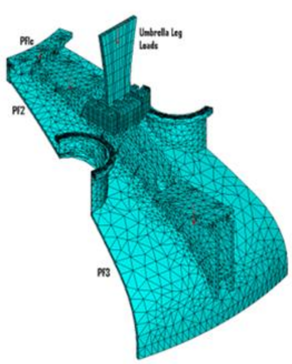
NSTX Upgrade

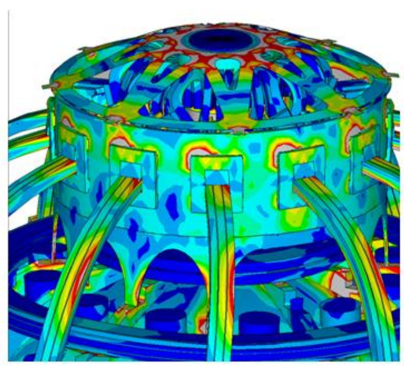
Umbrella Arch and Foot Reinforcements, Local Dome Details

NSTXU-CALC-12-07-00

Rev 0

May 2011





Prepared By:

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Peter Titus, PPPL Engineering Analysis Branch, Contributing Authors: H. Zhang

Reviewed By:

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Irv Zatz

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Mark Smith, NSTX Cognizant Engineer

PPPL Calculation Form

Calculation # **NSTXU-CALC-12-04-00** Revision # 00 WP #, 0029,0037 (ENG-032)

Purpose of Calculation: (Define why the calculation is being performed.)

The purpose of this calculation is to qualify the umbrella structure for increased loads and needed modifications for the NSTX CS Upgrade

References (List any source of design information including computer program titles and revision levels.)

-See the reference list in the body of the calculation

Assumptions (Identify all assumptions made as part of this calculation.)

The OOP loads on the umbrella structure were derived from the global model[1] of the outer leg that did not include the knuckle clevis restraint/support.

Calculation (Calculation is either documented here or attached)

Attached in the body of the calculation

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

With recommended reinforcements, the 3/4 inch 316 bolts are acceptable for the upgrade loads. DCPS input has been generated and provided to the DCPS Cognizant Engineer. At this writing, weld details of the recommended reinforcement are too high. and the reinforcement needs to be increased in strength by integrating it with the TF strap support.

Cognizant Engineer's printed name, signature, and date

Mark Smith ____

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date

Mark Smith ____

2.0 Table of Contents
Umbrella Arch and Foot Reinforcements, Local Dome Details

3.0 Executive Summary:

The umbrella structure is a part of the global TF Out-of-Plane (OOP) torque structure. The upper and lower ends of the TF outboard legs are connected to the umbrella structure by aluminum block clamps/split blocks. The aluminum blocks and the local details of the umbrella structure that support these loads are discussed and qualified in reference [4]. The umbrella structure also is attached to the spoked lids at their OD. Some of the machine torque is transferred to the central column through these attachments. The spoked lid is considered in reference [9]. Included in this calculation are the umbrella reinforcement, the feet or sliding pads at the vessel head ends of the umbrella legs, the ribs connected to the vessel that support the umbrella feet, and the vessel dished heads in the vicinity of the ribs. The proposed new solid umbrella leg is 4 inches thick - four times the thickness of the current legs. These analyses use a 3 inch thick leg, and this is adequate to obtain acceptable stresses. The new leg positions the welds in low stressed regions, and the welds are readily accessed, allowing large welds and plenty of margin. The dome is a 5/8 inch thick annealed 304 stainless head. It's yield is expected to be around 30 ksi. In Section 7 the bending allowable is determined to be 234 MPa. In the global model the dome stress was found to be less than 160 MPa and in the 30 degree cyclic symmetry model the peak dome stress is about half this - partly because only the locations away from the double arch can be treated in this model, and partly because it includes the tabs that joins the rib pairs. The 30 degree cyclic symmetry model does include the gap between the ribs and the dished head, and the tab details that bridge from the ribs to the dished head. These appear to be amply distributed and do not produce a stress locally in the tab, or tab weld beyond around 90 MPa. There is a higher stress at a weld that connects the umbrella foot sliding block to the ribs. This area is a candidate for periodic inspection.

With the increase in loading resulting from doubling the toroidal field and doubling the plasma current, the OOP loads increase by a factor of four for the Upgrade. This was addressed early in the project and the necessity to increase the load capacity of the umbrella legs was recognized. A number of concepts for improving the strength of the umbrella legs were investigated. The two main concepts that were considered were first to add flanges to the legs to turn them into cantelevered beams. This was judged to present a difficult in-situ fit-up and welding operation. Cover plates were also investigated. These would have been added to the legs on the inside and outside, but the field work required for these additions was also significant. The favored approach is to cut off the legs one by one and add a thicker leg. The weld used to re-connect the new leg is a horizontal weld on the inside and out. It is readily accessed, can be a very robust weld. The new, much thicker legs would be fabricated in the shop. The lower foot detail of the umbrella leg also needs upgrading. The portion attached to the leg can be an integral part of the leg and done in the shop as well.

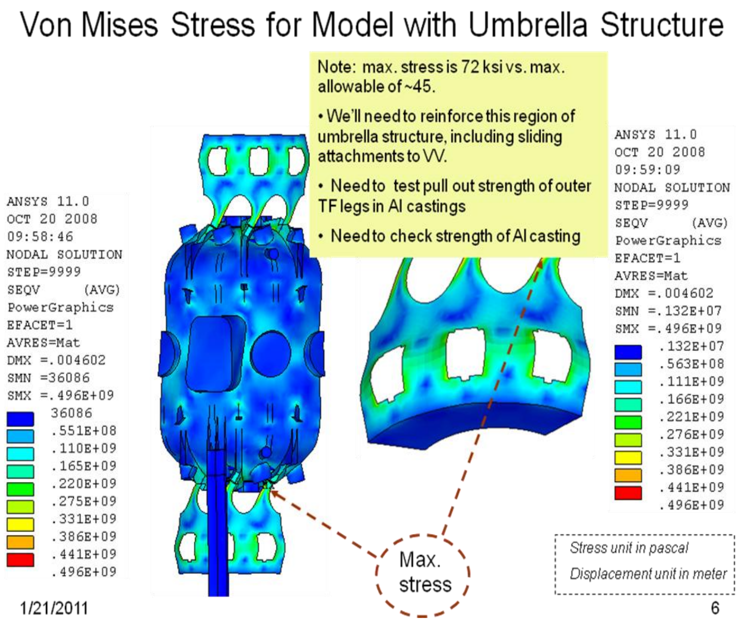

Figure 3.0-1-Required Reinforcement of the Umbrella Structure Legs [6]

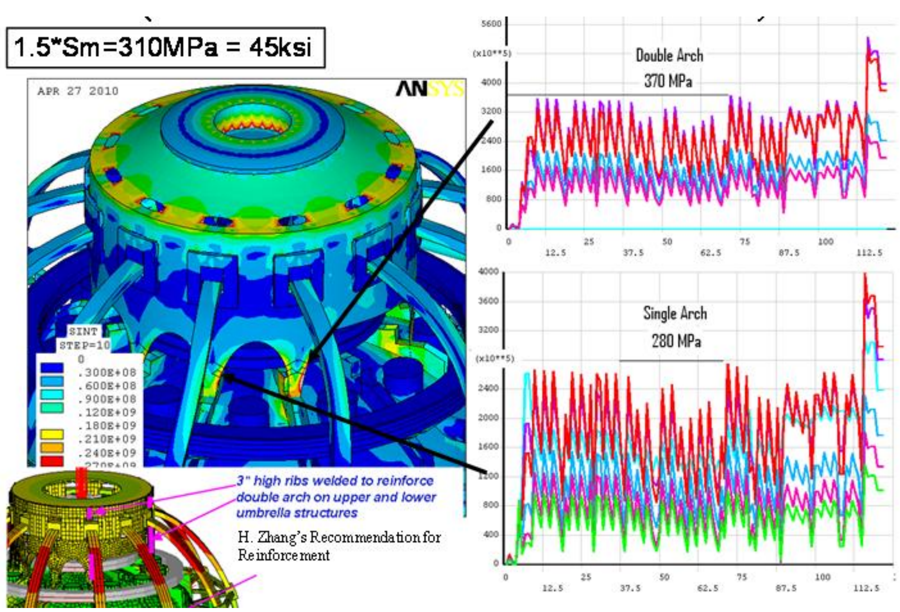

Figure 3.0-2 Need for Umbrella Structure Reinforcement

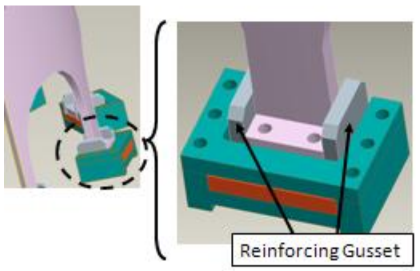

Figure 3.0-3

Analysis of the existing umbrella legs indicated a possibility of reinforcing only the double arch region. The bending allowable for the umbrella material had to be comparable to the cold worked value for the vessel shell of 45 ksi. The mill Cert for the Umbrella plate shows a yield of 32 ksi. and the design effort to reinforce the umbrella legs was continued. . For 304 stainless, a 180 MPa stress range translates to a 90/(1-90/500) = 109 MPa equivalent R=-1 alternating stress. This is a strain amplitude of 109/200000 = .05%. Entering the SN curve (Figure 7.2.1 for 304 Stainless) and applying either 2 on stress or 20 on life yields an acceptable fatigue life meeting the GRD requirement of 60000 pulses. Figure 9.3.4 shows an area where stress concentrations are expected and which is a candidate for periodic inspection.

The umbrella support feet are mounted on sliding blocks that attach to the vessel head rib weldment. These must transfer the OOP loading from the TF outer legs as well as vertical loads. The sliding feature is intended to allow the unrestrained growth of the vessel during bake-out. In the present design, the foot is held to the weldment with four bolts that connect through the welded plate and are loaded in shear by the OOP loading. The sliding feet assembly will be replaced with stronger components. The base of the slider will have lips to capture the welded plate to takes the shear off the bolts.

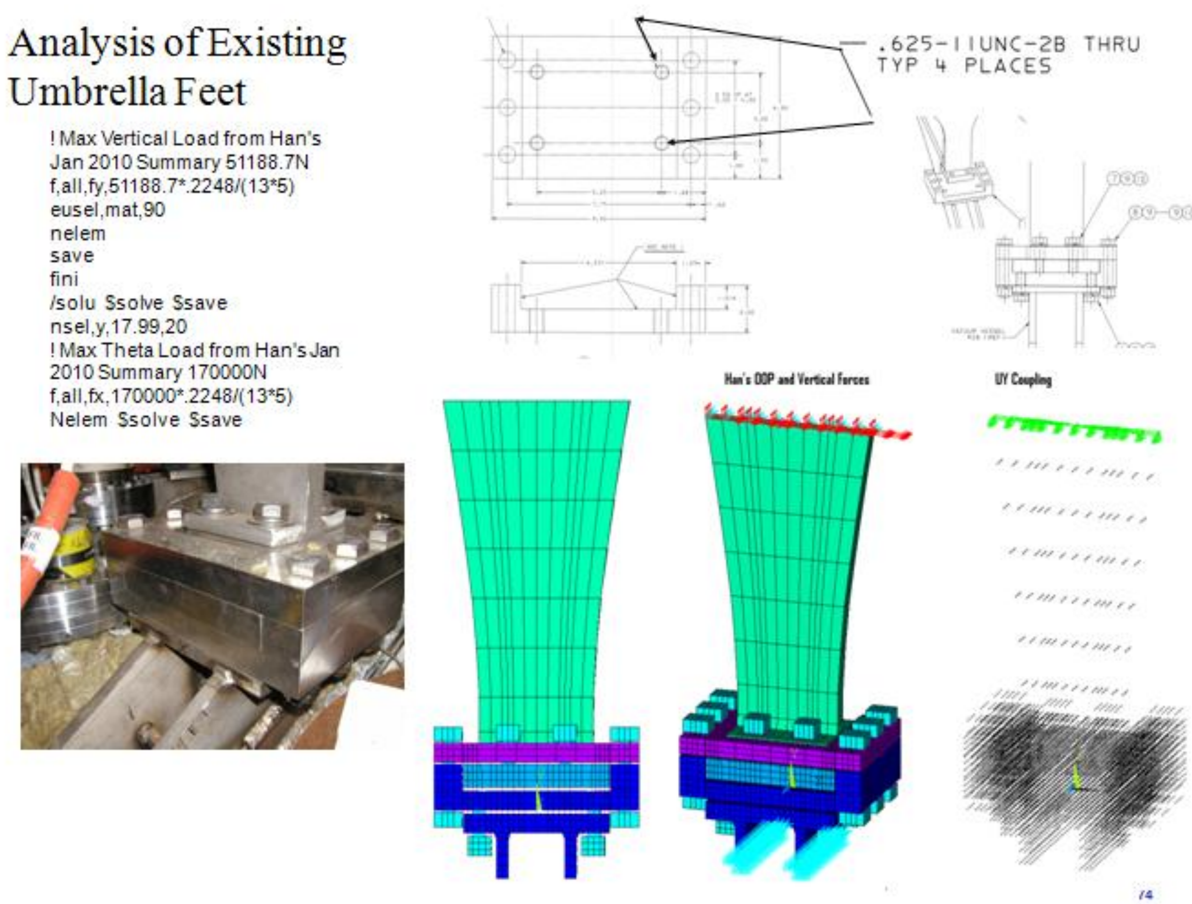

Figure 3.0-4 Local Model -Only the Umbrella Leg and Foot

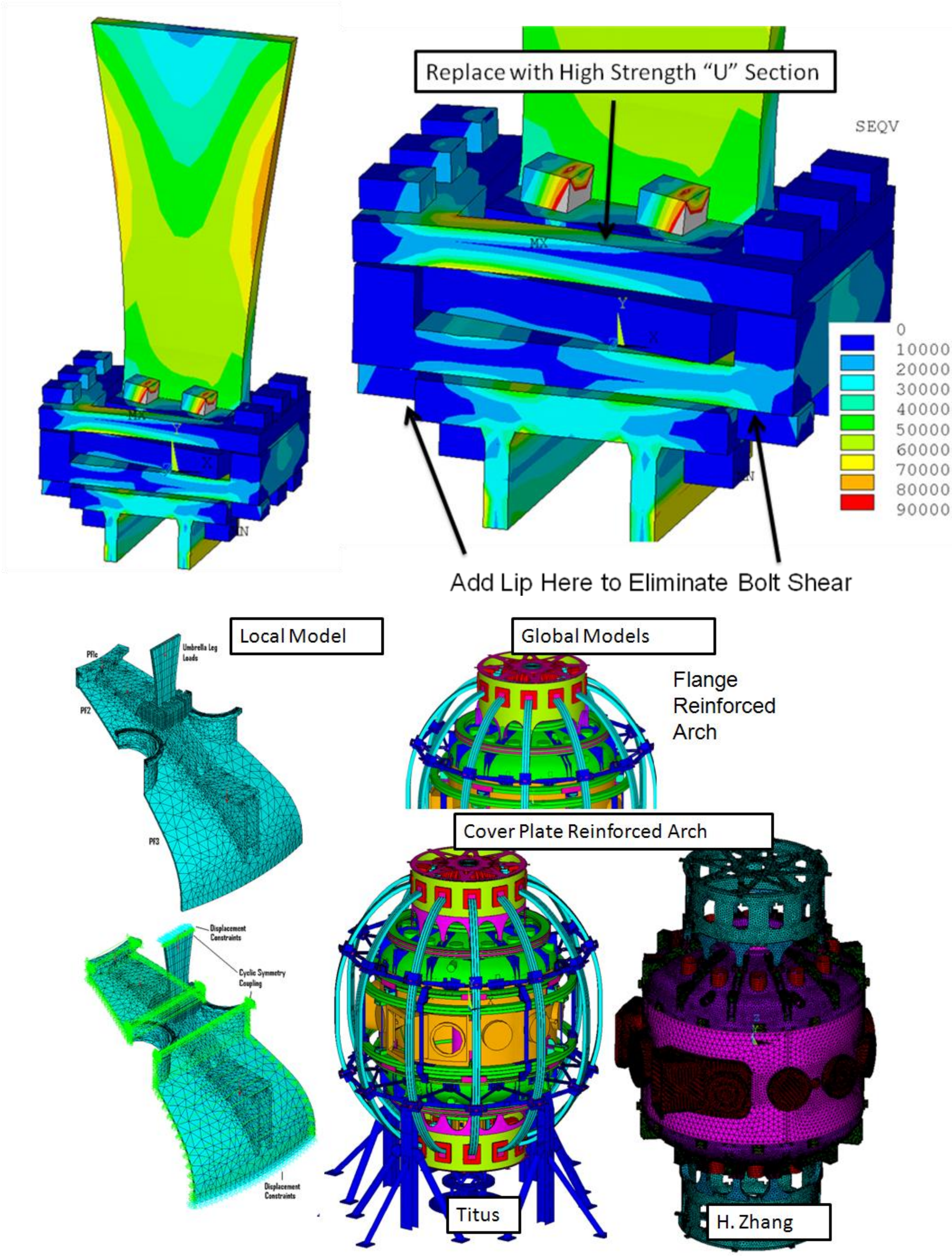

Figure 3.0-5 Local 30 Degree Cyclic Symmetry Model -and Global Models

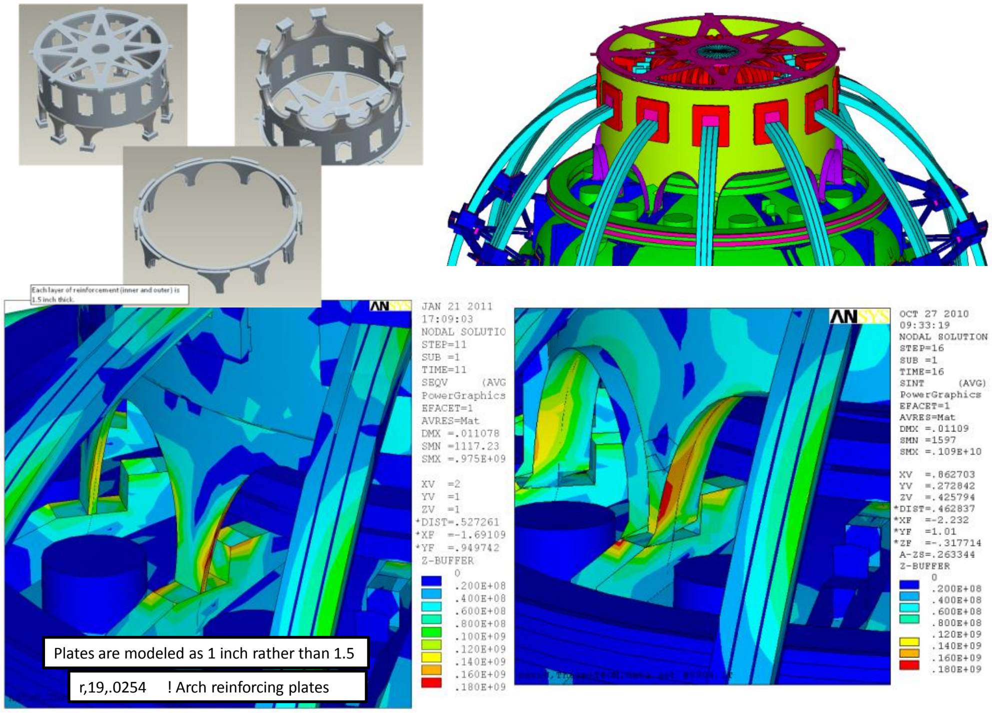

Figure 3.0-6 Results of two Reinforcement Concepts.

Two models of the support ribs that are welded on the vessel are used. The local 30 degree cyclic symmetry model was meshed from a ProE solid model developed by Bruce Paul from the Non-Conformance Reports for the rib welds. The ribs were cut to the expected profile of the dished head, but the profile was not perfect, and there were gaps between the ribs and vessel that needed to be bridged with tabs. The welds used were substantial and were dispositioned by H. M. Fan. The tabs between the welds stiffen the pair of ribs, and this feature was not included in the global model. The global model stresses are above the 30 degree cyclic symmetry model. The lack of tabs may be the reason. The higher stresses in the global model at the double arch are real.

5.0 Design Input

5.1 References

[1] NSTX-CALC-13-001-00 Rev 1 Global Model – Model Description, Mesh Generation, Results, Peter H. Titus December 2010

[2] NSTX Structural Design Criteria Document, I. Zatz

[3] NSTX Design Point June 2010 http://www.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html

[4] TF to Umbrella Structure Aluminum Block Connection NSTXU-CALC-12-04-00Rev 0 December 15 2010

[5] NSTXU-CALC-132-04-00 ANALYSIS OF TF OUTER LEG, Han Zhang, August 31, 2009

[6] Webmeeting of 10/20 2008 attended by L. Dudek, R. Parsells, J. Chrzanowski, M. Williams, M. Ono, R. Woolley, P. Titus, P. Heitzenroeder included in this presentation: NSTX Center Stack Upgrade Preliminary V.V. Analysis H.M. Fan, 10/20/2008

[7] Center Stack Casing Bellows, NSTXU-CALC-133-10-0 Prepared by Peter Rogoff.

[8] Email from Art Brooks Thu 3/11/2010 8:21 AM, providing Upper and Lower design loads for the centerstack casing halo loads, copy of the email is included in the appendices

[9] WBS 1.1.2 Lid/Spoke Assembly, Upper & Lower NSTX-CALC-12-08-00 Rev 0 May 2011 Prepared by P. Titus

[10] Dome Material Certifications Included in Appendix B "

[11] Umbrella Structure Mill Certs , Email from Larry Dudek October 8 2010

Pete,

Mark found the certs for the umbrellas. Yield stress: 32ksi

Larry

[12] Analysis of TF Outer Leg, NSTXU-CALC-132-04-00,Prepared By: Han Zhang, Reviewed by Peter Titus Cognizant Engineer: Mark Smith

5.4 Drawings and Photos of Existing Components

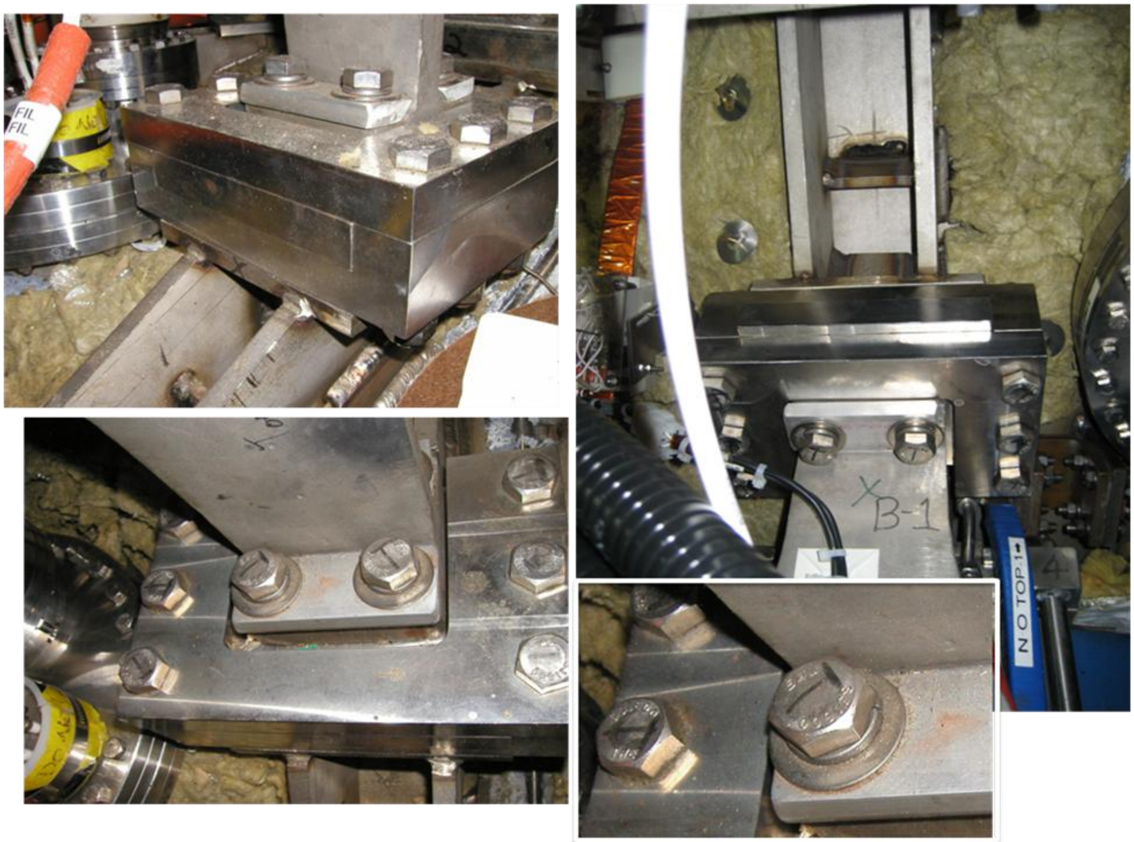

Figure 5.4-1 Photos of the Umbrella Foot Details

Figure 5.4-2 Photo of the One of the Tabs that Connect Rib Pairs

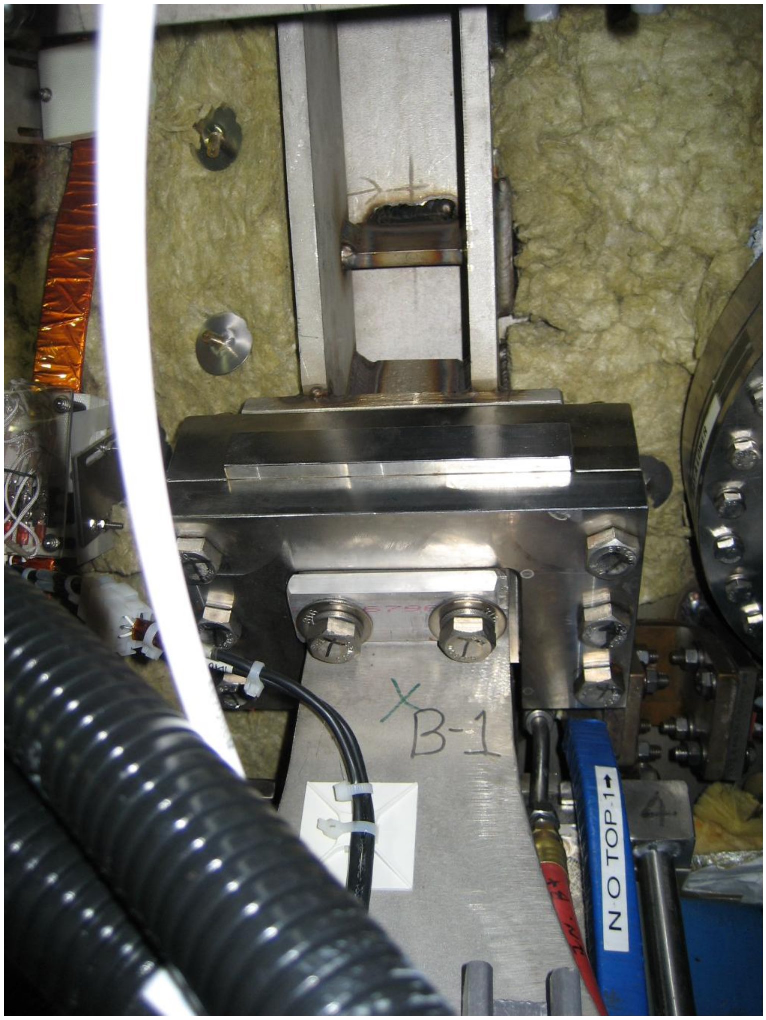

Figure 5.4-3 Photo of the One of the Lower Umbrella Sliding Feet.

Table 5.4-1 Loads from the Design Point Spreadsheet.

Fz(lbf)	PF1cU	PF2U	PF3U	PF3L	PF2L	PF1cL
Min	-30125	-67757	-148839	-31442	-42996	-68673
Worst Case Min	-168089	-194414	-303940	-246951	-192144	-143125
Max	68673	42996	100954	148839	54525	30125
Worst Case Max	143125	192144	246951	303940	194414	168089

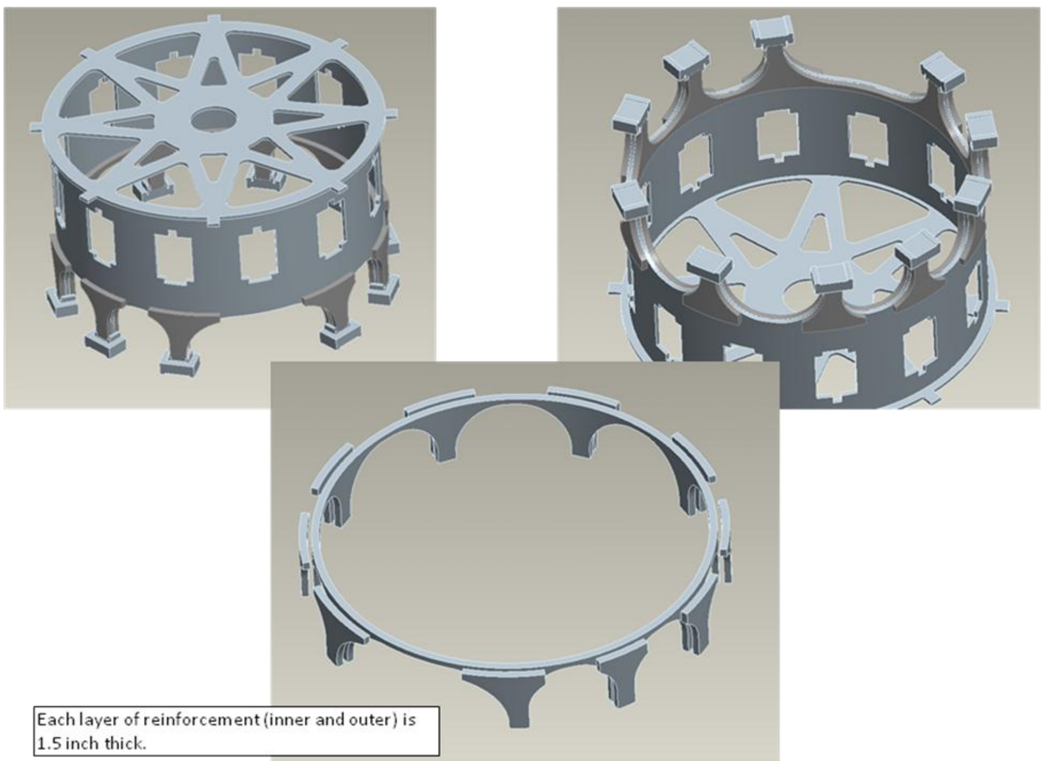

Table 5.4-1: Calculated Force on Aluminum block, From Ref [5]

		ss case no effective		**link to vacuum vessel: bar1, 2 and 3 have different orientations**		
	no truss	**adding case (0.5" thick, 12" wide)**	**adding ring (0.5x12" rect, welded)**	**adding bar1 (3x3" rect, pin connected)**	**adding bar2 (3x3" rect, pin connected)**	**adding bar3 (3x3" rect, pin connected)**
Total end reaction force (kN)	**297**	**294**	**269**	**239**	**249**	**224**
End reaction force r (kN)	245.71	245.96	223.2	212.98	225	192.09
End reaction force theta (kN)	166.49	161.03	149.95	105.98	105.95	106.05
End reaction	11.956	10.3	10.155	19.366	9.2544	44.565

force z (kN)	

6.0 Analysis Models
6.1 Global Model

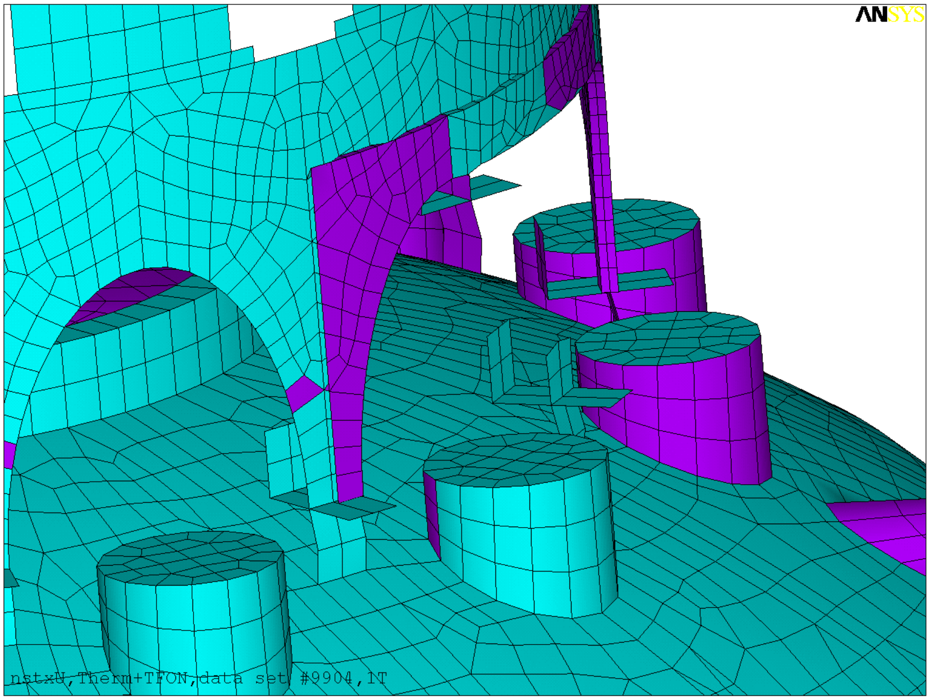

Figure 6.1-1 Global Model Umbrella Arch Region. -Overlay Plates

The arch cover plates are modeled with a layer of plate elements on the outside and the inside. Meshed by repeating the Umbrella leg plate elements and bridging the gaps with a thin lines of plate elements. This model is used to assess the stresses in the solid leg configuration as well.

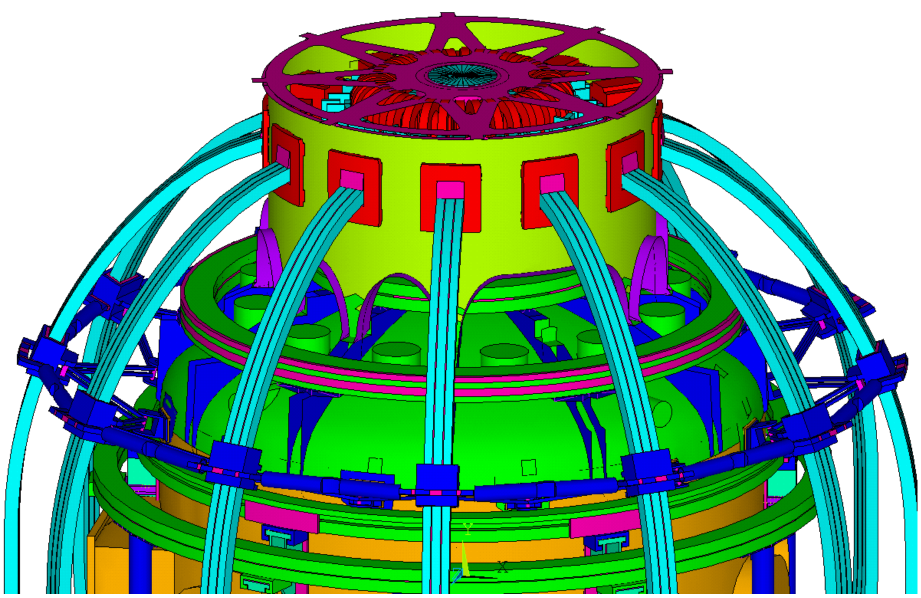

Figure 6.1-2 Global Model Umbrella Arch Region. - Flange Addition

In this model, flanges have been added to the arches, forming I-Beams as legs.

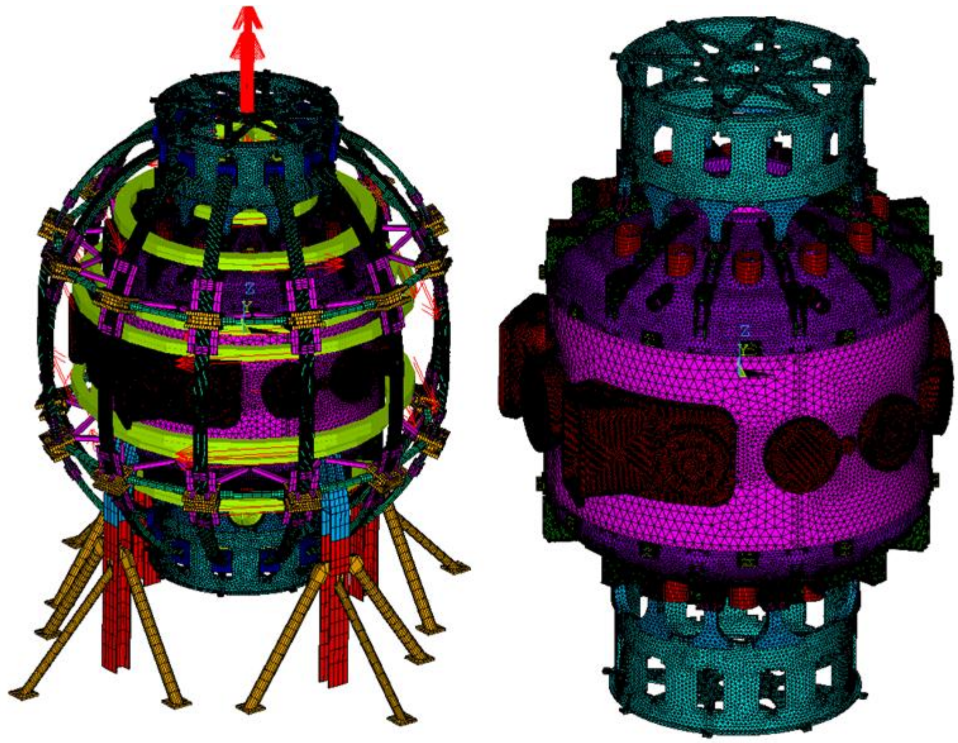

Figure 6.1-3 Han Zhang's Global Model, Reference [12]

6.2 Arch and Feet Local Models

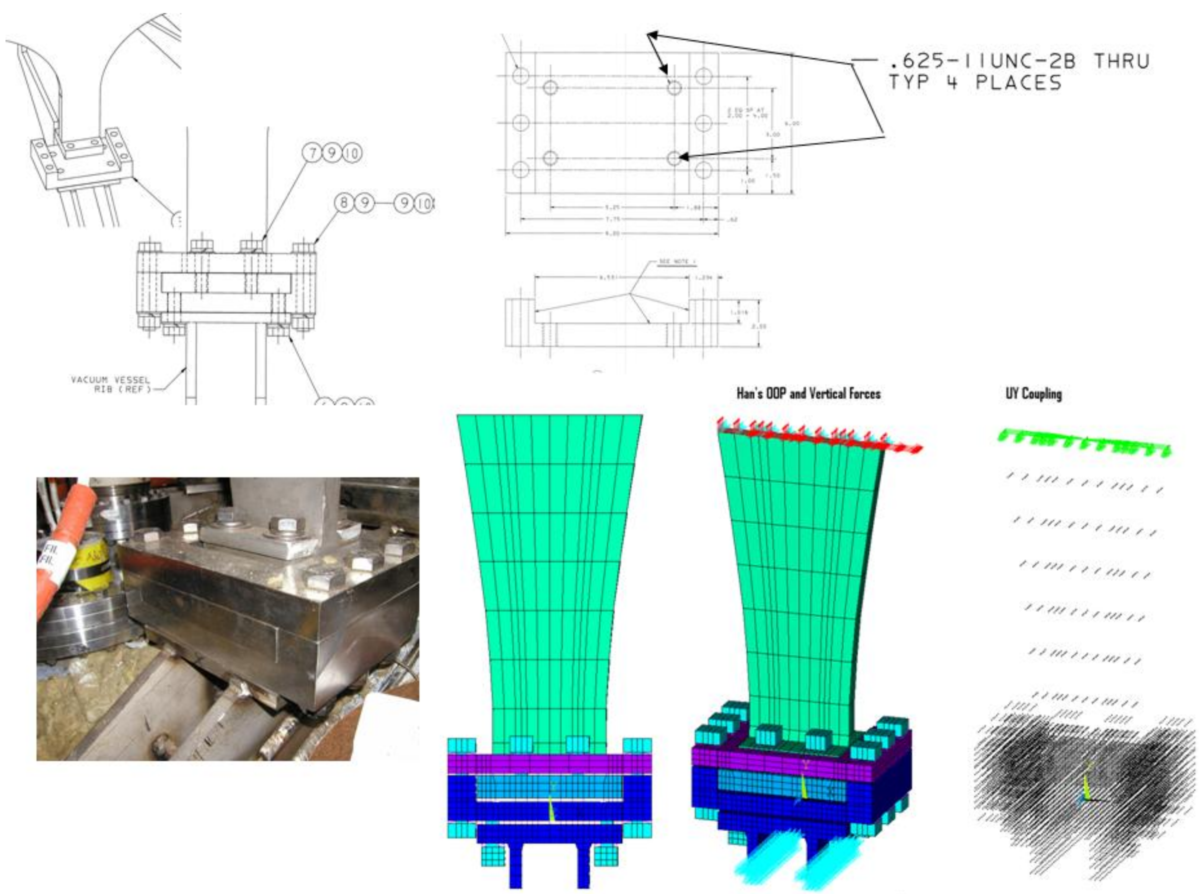

Figure 6.2-1 Local Model of only the Umbrella Leg Foot

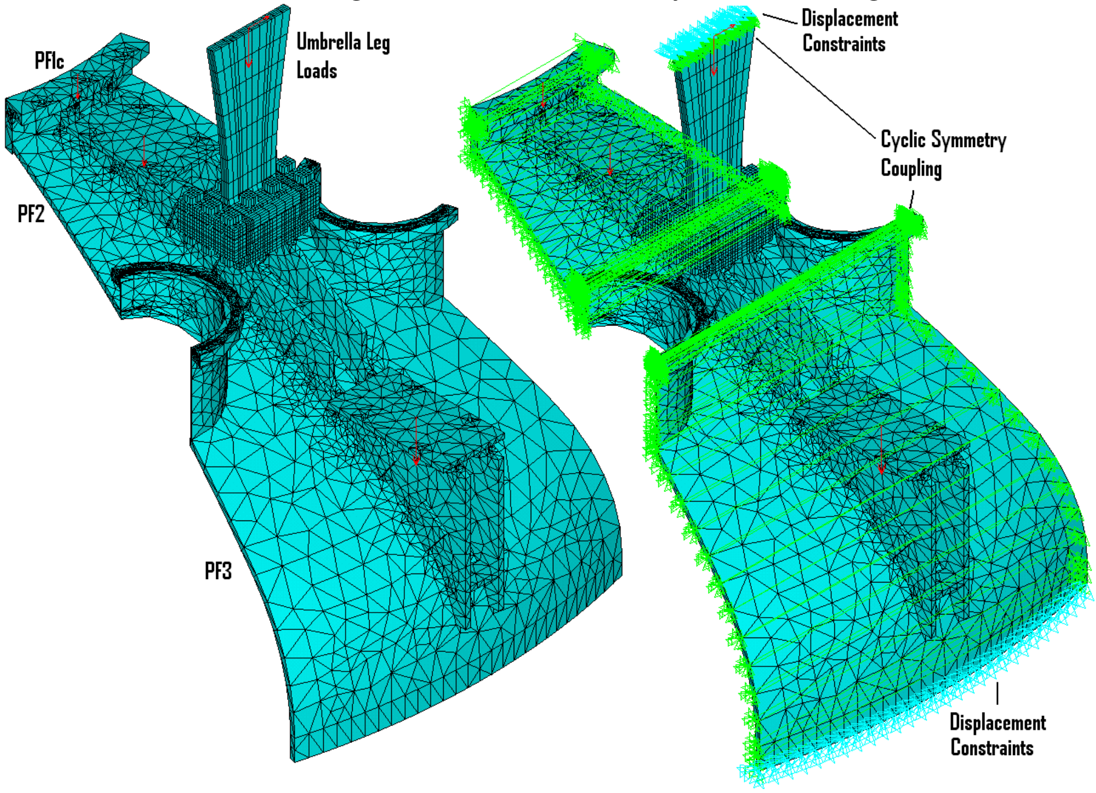

Figure 6.2-2 Local Model of Umbrella Leg Foot and Dome/Rib from As-Builts

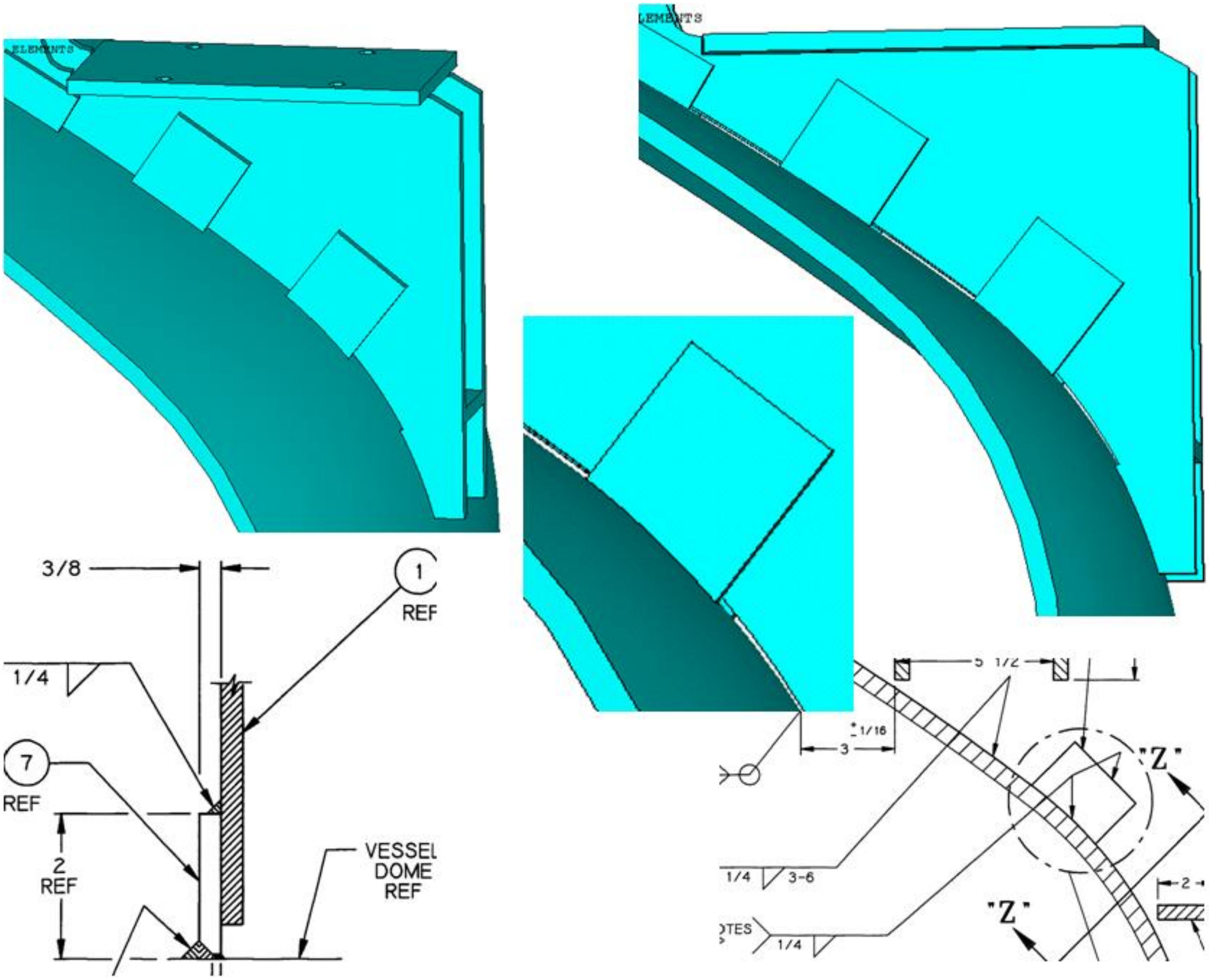

Figure 6.2-3 Local Model of Rib Showing Gaps and Modeling of The Non-Conformance Disposition

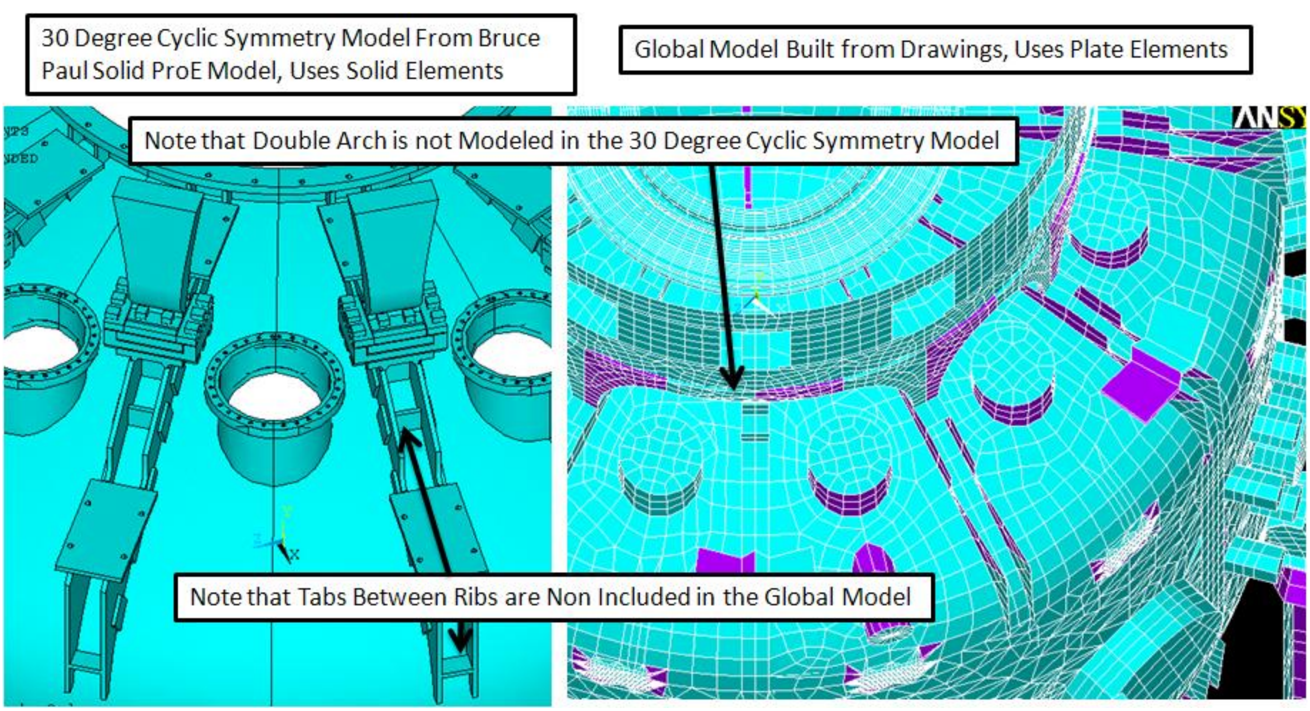

Figure 6.2-4 Comparison of 30 degree Cyclic Symmetry Model and the Global Model

Two models of the support ribs, that are welded on the vessel, are used. The local 30 degree cyclic symmetry model was meshed from a ProE solid model developed by Bruce Paul from the Non-Conformance Reports for the rib welds. The ribs were cut to the expected profile of the dished head, but the profile was not perfect, and there were gaps between the ribs and vessel that needed to be bridged with tabs. The welds used were substantial and were dispositioned by H. M. Fan. The tabs between the welds stiffen the pair of ribs, and this feature was not included in the global model. The global model stresses are above the 30 degree cyclic symmetry model. The lack of tabs may be the reason. The higher stresses in the global model at the double arch are real.

ANSYS ADPL Loading Commands for the 30 Degree Cyclic Symmetry Model

```
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f,402,fz,-67757/11/.2248      !PF2
f,4588,fz,-100000     !Umb Foot
f,1237,fz,-148839/11/.2248     !PF3
solve
f,4588,fy,60000
/title,PF4 and PF5 Upper Loads Plus TF OOP Loads
solve
save
/title,OOP Loads Only
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f,4588,fz,.001
f,1237,fz,.001     !PF3
solve
save
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f,402,fz,-194414/11/.2248      !PF2
f,4588,fz,-100000     !Umb Foot   (From the table in the input section based on [5] this should be 106000N)
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save
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```

6.2.2 Arch and Feet Local Model Run Log and Run Files

Foot01.txt -30 degree cyclic Symmetry Model in \nstx\csu\dome, 3/4 inch thick Umbrella Leg
Foot02.txt -30 degree cyclic Symmetry Model in \nstx\csu\dome, 3 inch thick Umbrella Leg
Global Model Run #28 and beyond model the overlay plates or solid leg

7.0 Materials and Allowables

7.1 Stainless Steel Static Stress Data

Table 7.1-1Tensile Properties for Stainless Steels

Material	Yield, 292 deg K (MPa)	Ultimate, 292 deg K (MPa)
316 LN SST	275.8[7]	613[7]
316 LN SST Weld	324[7]	482[7] 553[7]
316 SST Sheet Annealed	275[8]	596[8]
316 SST Plate Annealed		579
304 Stainless Steel (Bar,annealed)	234 33.6ksi	640 93ksi
304 SST 50% CW	1089	1241 180ksi

Table 7.1-2 Coil Structure Room Temperature (292 K) Maximum Allowable Stresses, Sm = lesser of 1/3 ultimate or 2/3 yield, and bending allowable=1.5*Sm

Material	Sm	1.5Sm
316 Stainless Steel	184	276
316 Weld	161	241
304 Stainless Steel (Bar,annealed)	156MPa(22.6ksi)	234 MPa (33.9ksi)

Material	Sm	1.5Sm
304 Stainless Steel (Bar,annealed)	156MPa(22.6ksi)	234 MPa (33.9ksi)

Note that the Material Certifications for the dome indicate that the dome is annealed 304. The material Certs are included in ref[10], Appendix B

7.2 Stainless Steel Fatigue Data

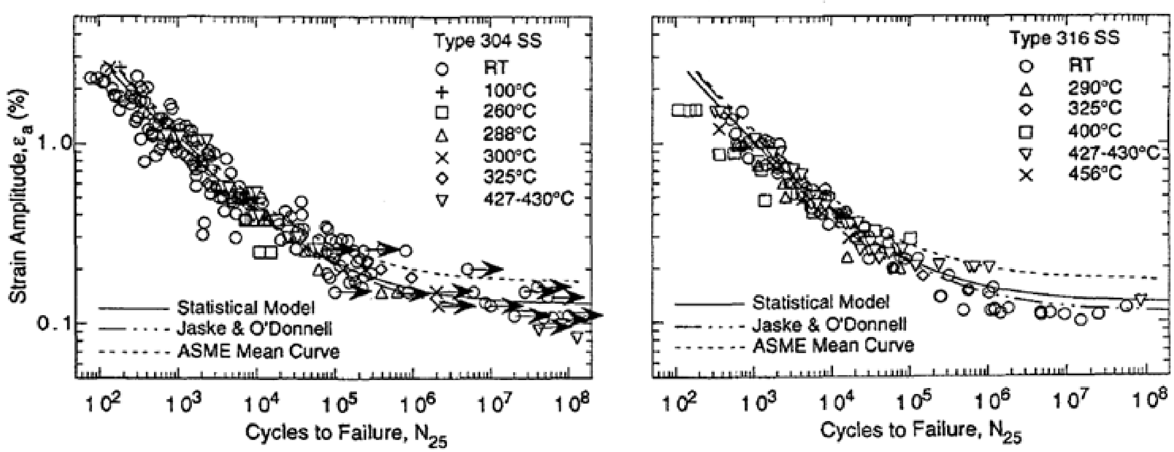


Figure 7.2-1 Fatigue Data for 304 and 316 Stainless Steels
From Tom Willard's Collection of SST Fatigue Data
"Estimation of Fatigue Strain-Life Curves for Austenitic in Light Water Reactor Environments Stainless Steels", Argonne Nat. Lab, 1998

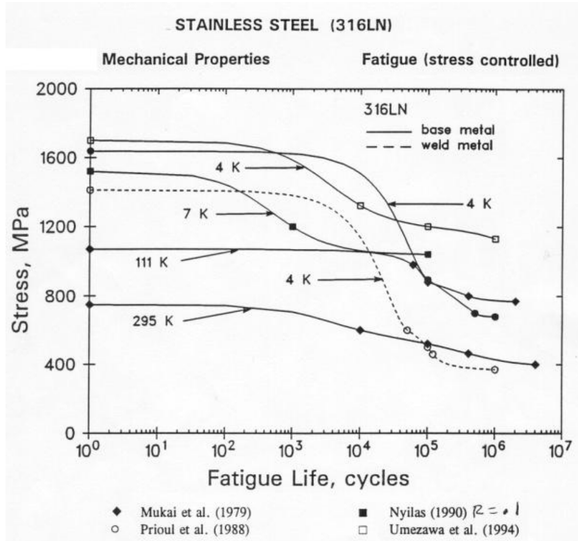


Figure 72-2 Fatigue S-N Curve for 316 Stainless Steel

7.3 Stainless Steel Fatigue Data

ASTM A193 Bolt Specs from PortlandBolt.com

B8M	Class 1 Stainless steel, AISI 316, carbide solution treated.
B8	Class 2 Stainless steel, AISI 304, carbide solution treated, strain hardened
B8M	Class 2 Stainless steel, AISI 316, carbide solution treated, strain hardened

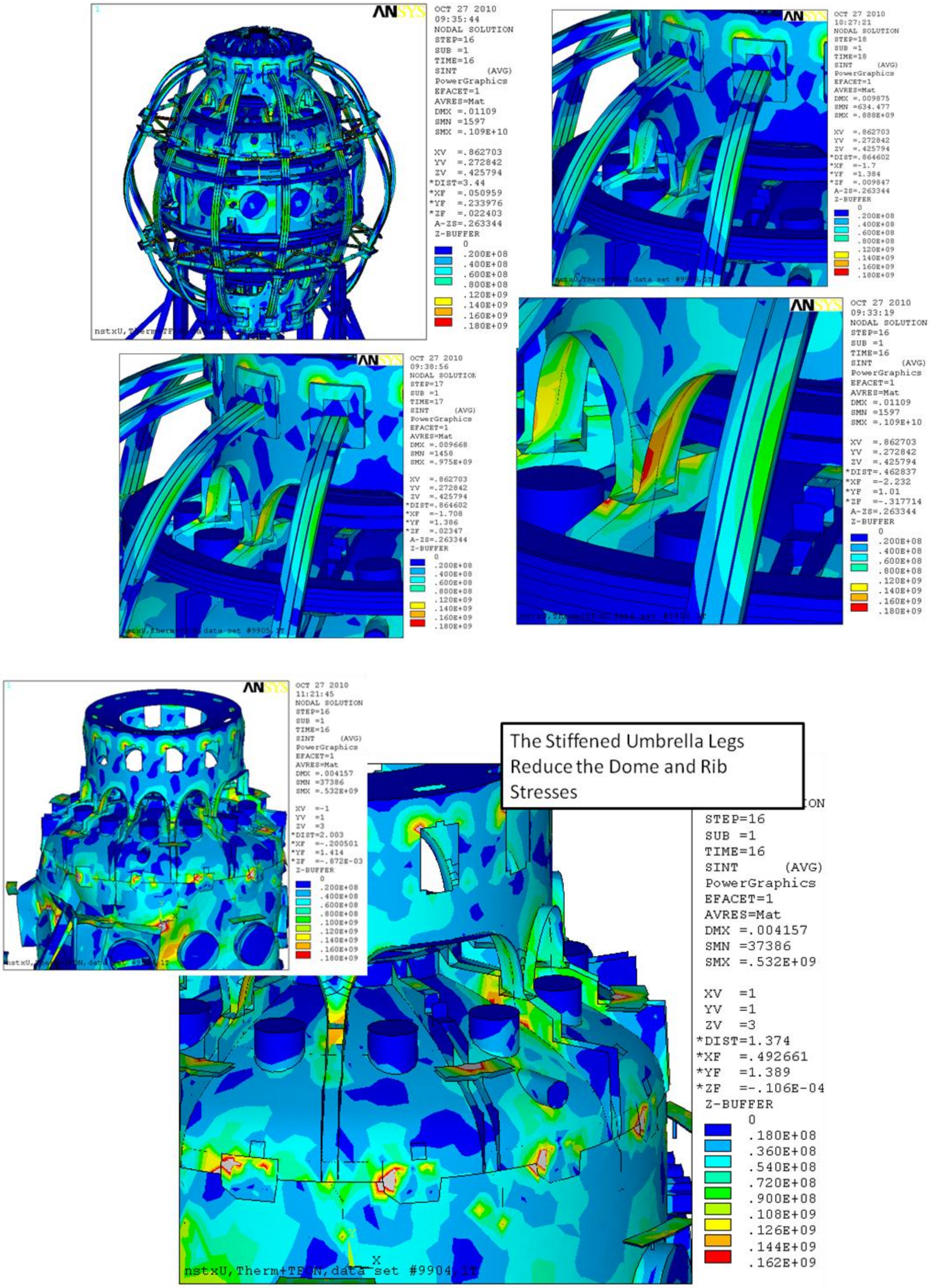
Mechanical Properties

Grade	Size	Tensile ksi, min	Yield, ksi, min	Elong, %, min	RA % min
B8 Class 1	All	75	30	30	50
B8M Class 1	All	75	30	30	50
B8 Class 2	Up to 3/4	125	100	12	35
	7/8 - 1	115	80	15	35
	1-1/8 - 1-1/4	105	65	20	35
	1-3/8 - 1-1/2	100	50	28	45
B8M Class 2	Up to 3/4	110	95	15	45
	7/8 - 1	100	80	20	45
	1-1/8 - 1-1/4	95	65	25	45
	1-3/8 - 1-1/2	90	50	30	45

8.0 Global Model Resultss

8.1 Arch Reinforcements

8.1.1 Addition of Flanges



8.1.2 Cover Plates inside and out

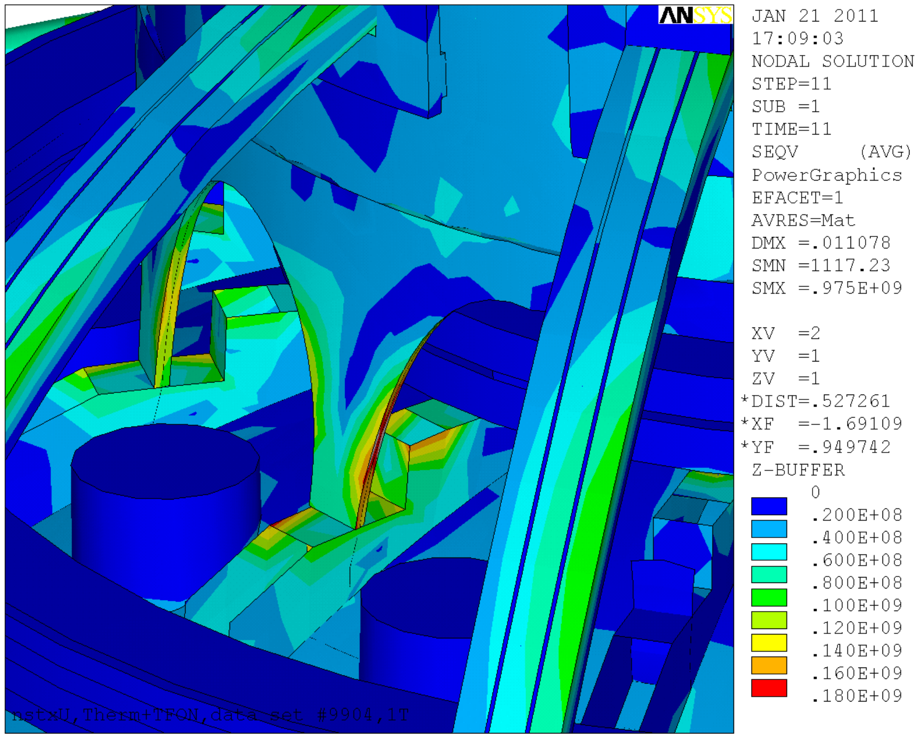


Figure 8.1.2-1 Typical Cover Plate Stress

Use of cover plates in this concept puts the welds at the high stress edge of the umbrella legs. If this model is interpreted as modeling 3 inch thick solid legs - replacing the existing 1 inch thick legs then the high stress is not in a region of the weld. The horizontal weld - represented by the upper edge of the cover plate in this model, is in a low stress region.

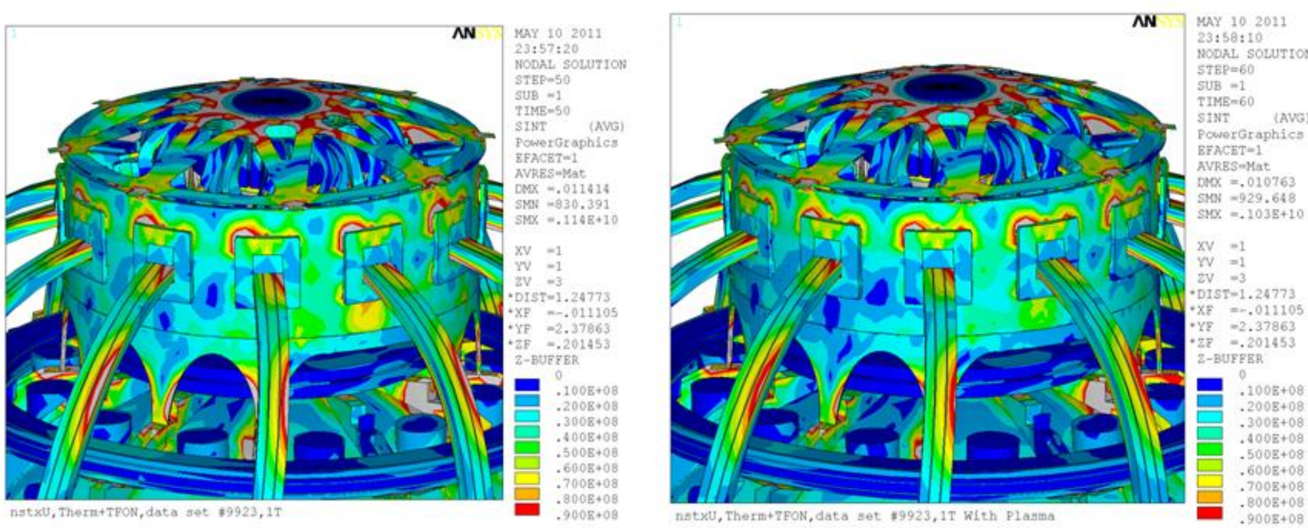


Figure 8.1.2-2 Cover Plate Stress Results

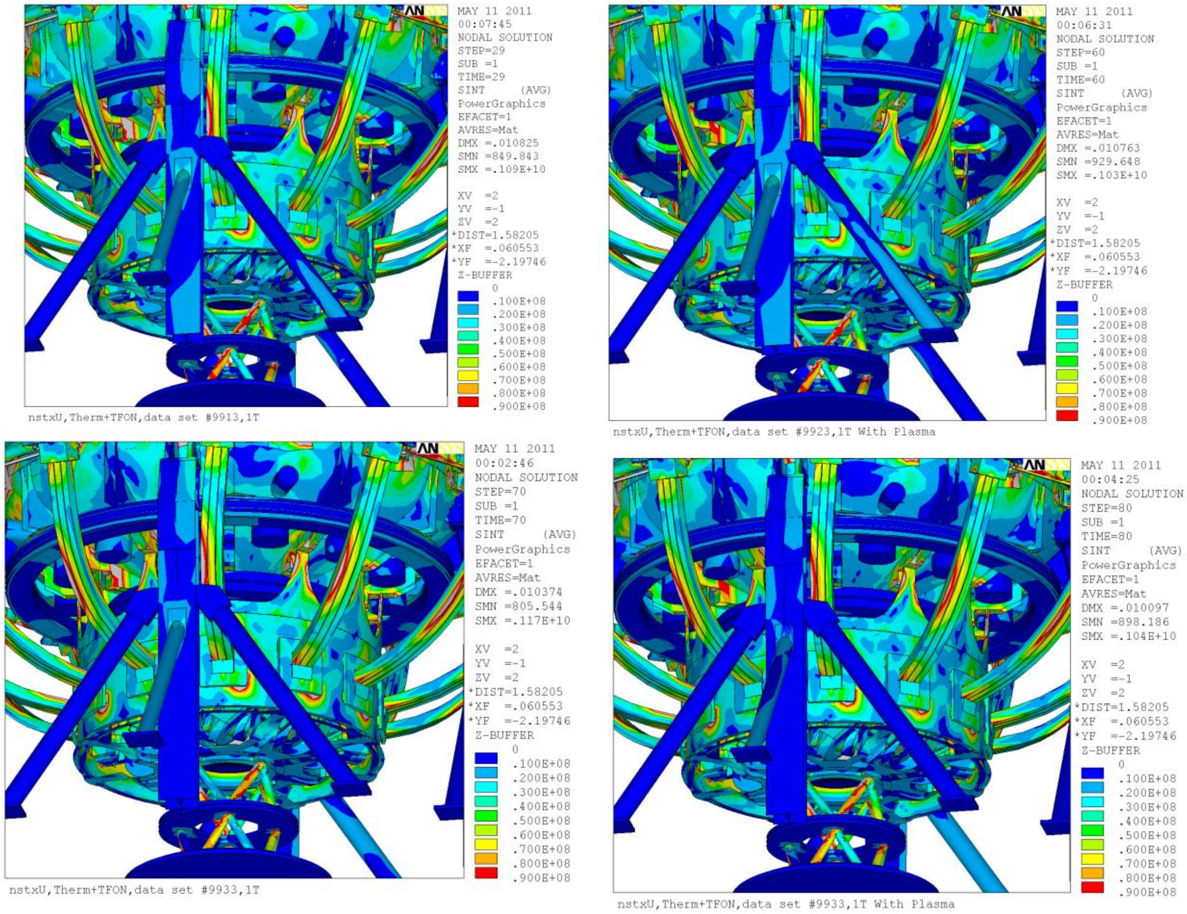
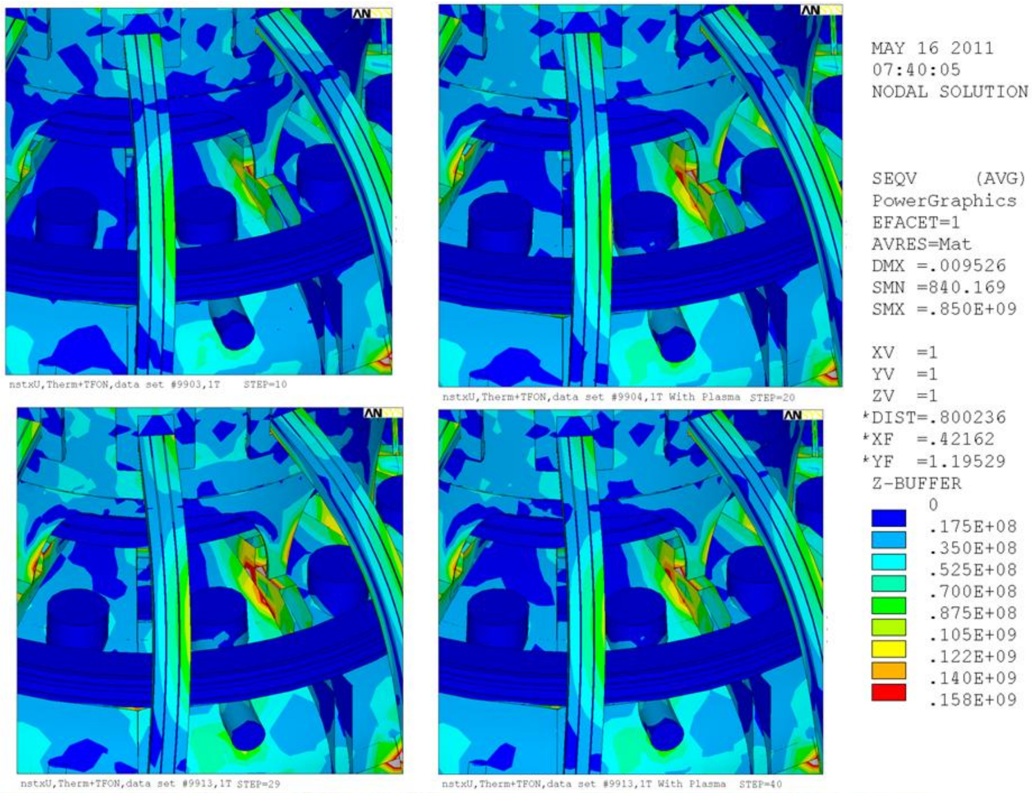
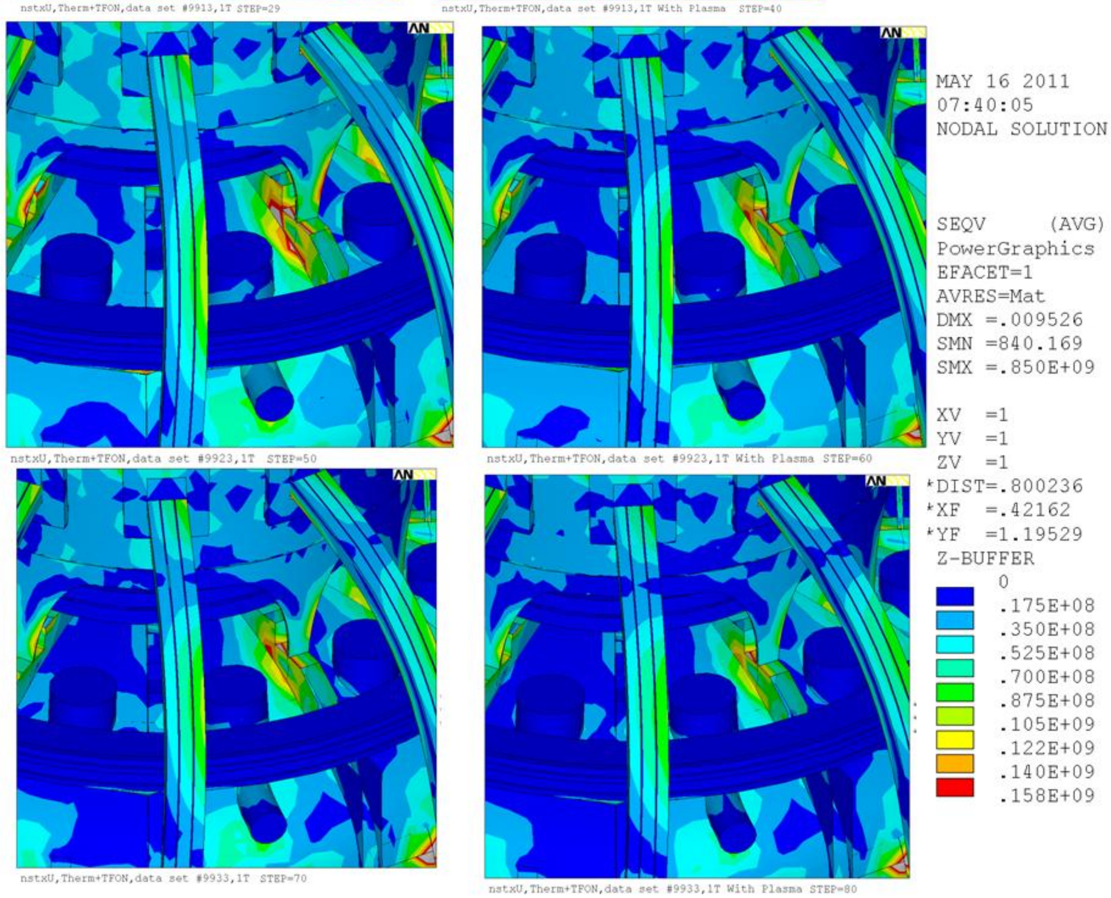


Figure 8.1.2-2 Lower Umbrella Structure Cover Plate Stress Results

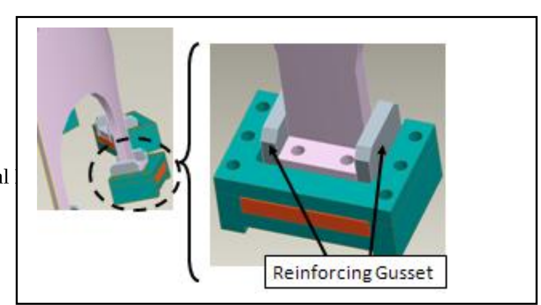
8.2 Dome/Rib Details



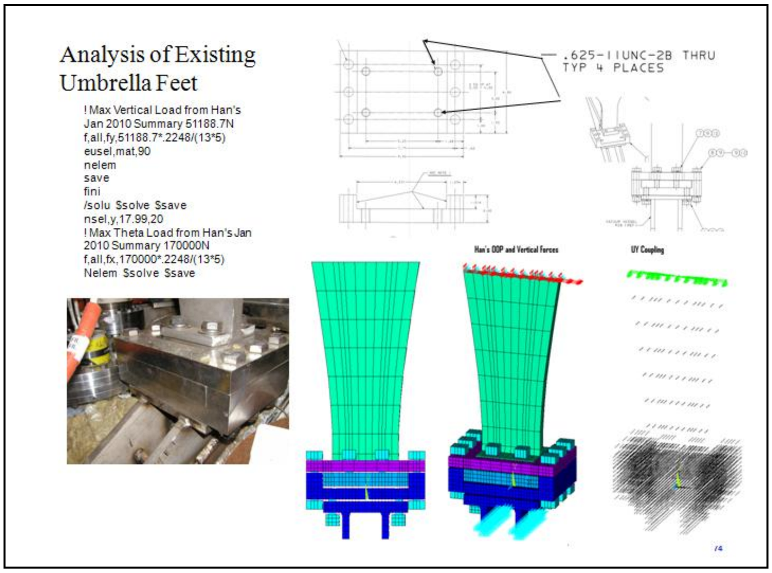


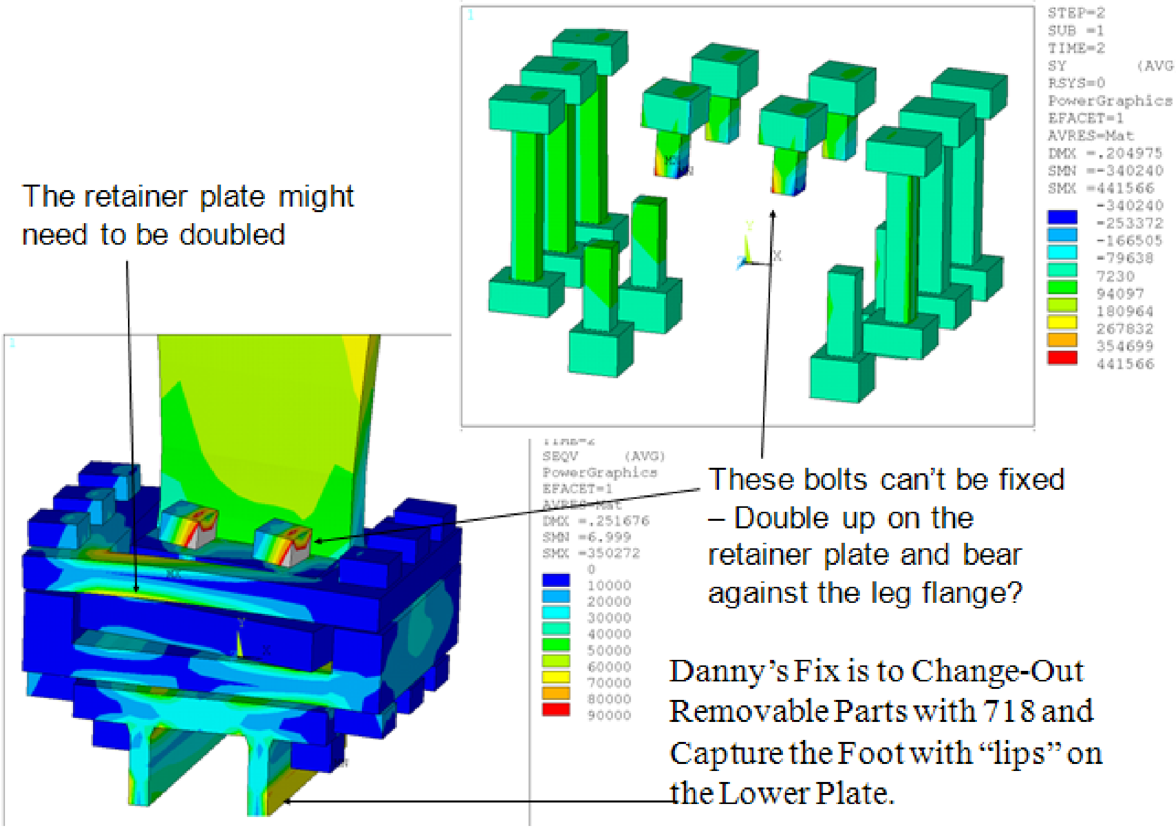
9.0 Local -Model Results

9.1 Existing Umbrella Feet Sliding Block Analyses



The umbrella support feet are mounted on sliding blocks that attach to the vessel head rib weldment. These must transfer the OOP loading from the TF outer legs as well as vertical loads. The sliding feature is intended to allow the unrestrained growth of the vessel during bake-out. In the present design, the foot is held to the weldment with four bolts that connect through the welded plate and are loaded in shear by the OOP loading. The sliding feet assembly will be replaced with stronger components. The base of the slider will have lips to capture the welded plate to takes the shear off the bolts.

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-340240
-253372
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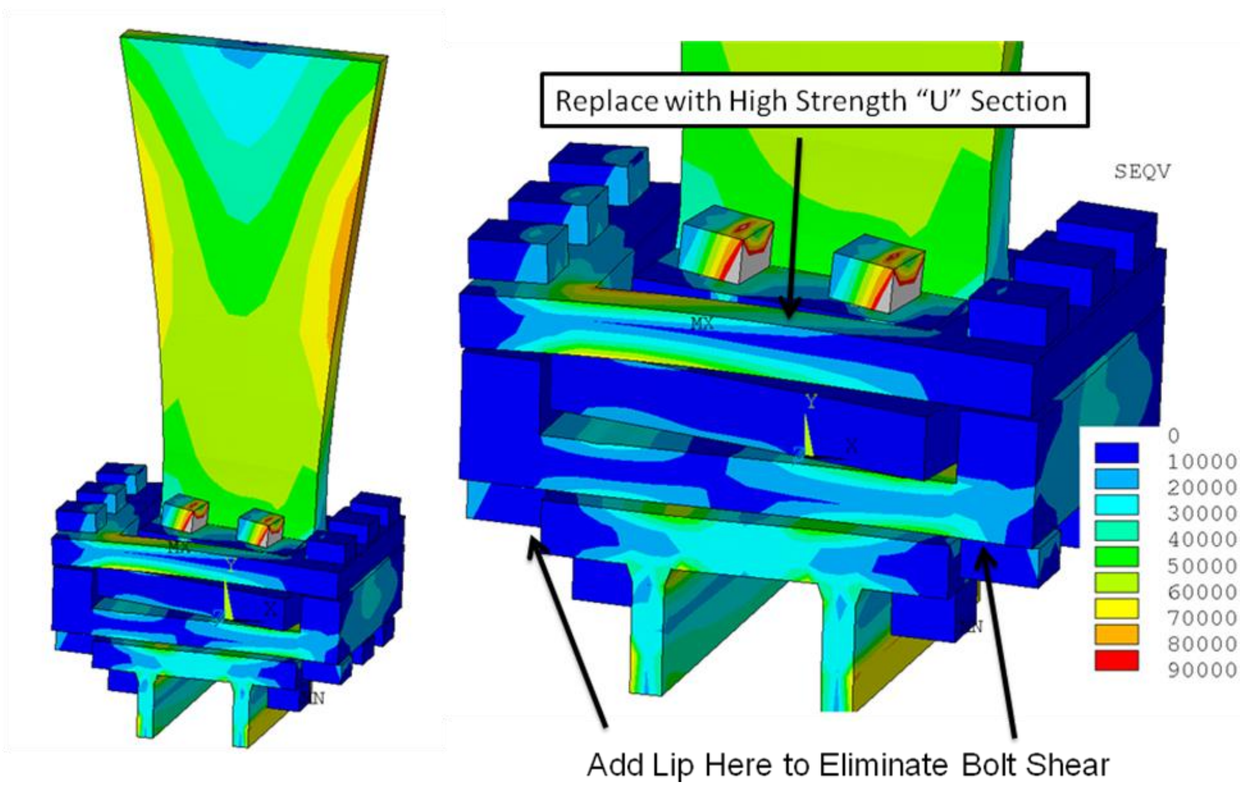
7230
94097
180964
267832
354699
441566
The retainer plate might need to be doubled
SEQV (AVG)
PowerGraphics
EFACET=1
DMX =.251676
SMN =6.999
SMX =350272
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
These bolts can't be fixed – Double up on the retainer plate and bear against the leg flange?
Danny's Fix is to Change-Out Removable Parts with 718 and Capture the Foot with "lips" on the Lower Plate.


Replace with High Strength "U" Section
SEQV
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Add Lip Here to Eliminate Bolt Shear

9.2 Umbrella Feet - With Dome Segment

This model integrates the umbrella leg/foot and the dome segment corresponding to a 1/12 sector of the machine. This is a non conservative assumption given that there are eleven umbrella feet, and the stresses peak at the double arch. The 3D model, described in section 8 captures this effect.

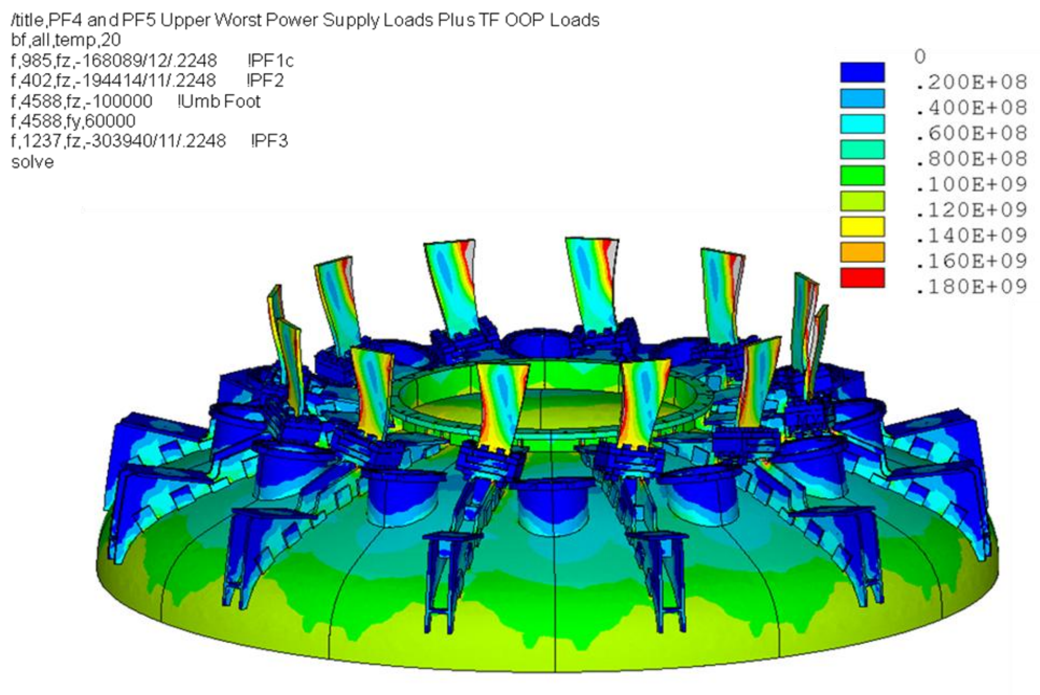


Figure 9.2-1 Model with 12 fold symmetry expansion

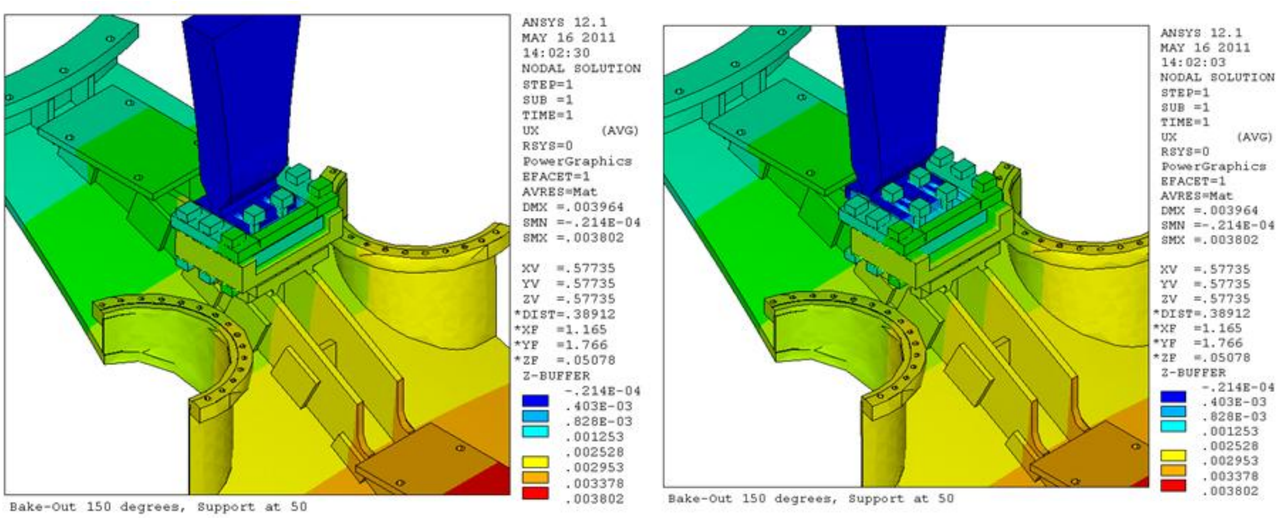


Figure 9.2-2 Bake-Out Radial Displacements

9.3 Dome/Rib Details

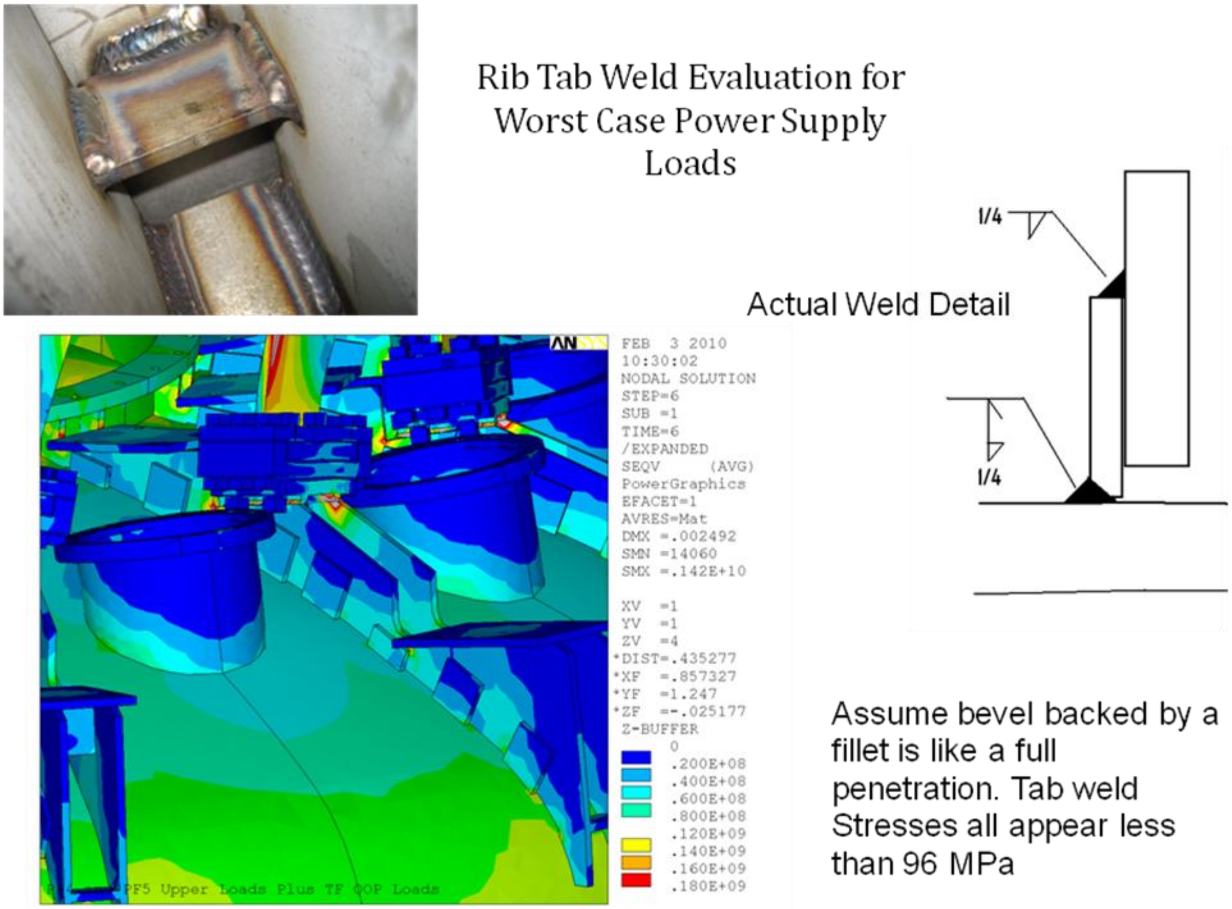


Figure 9.3-1 Rib Tab Detail and Stress. Note the High Stress Point at the End of the Weld - See Figure 9.3.4

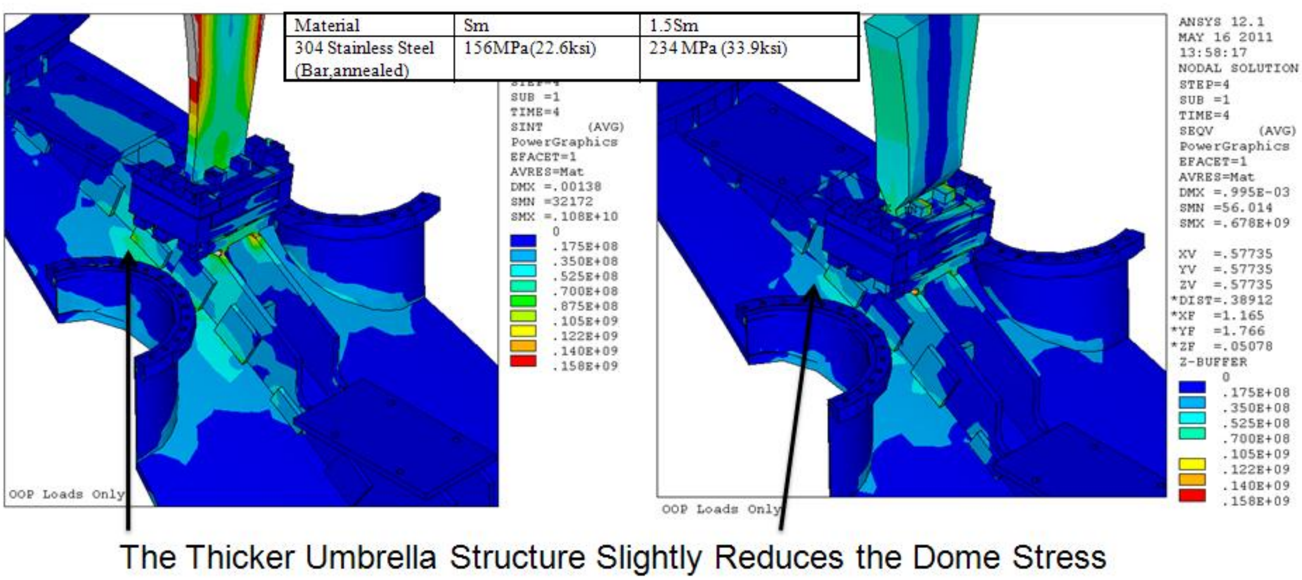


Figure 9.3.1 Effect of Umbrella Leg Stiffness on Dome Stress

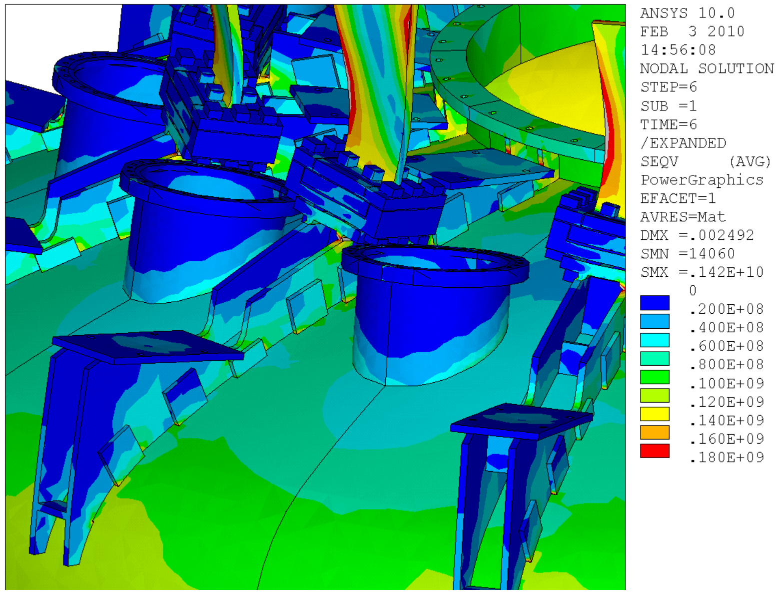


Figure 9.3.2 Stress Results with a 3/4 inch Umbrella Leg - Subsequent to this analysis the Umbrella Structure was found to be made from 1 inch plate, and the Upgrade reinforcement is to replace the legs with 3 to 4.5 inch thick legs

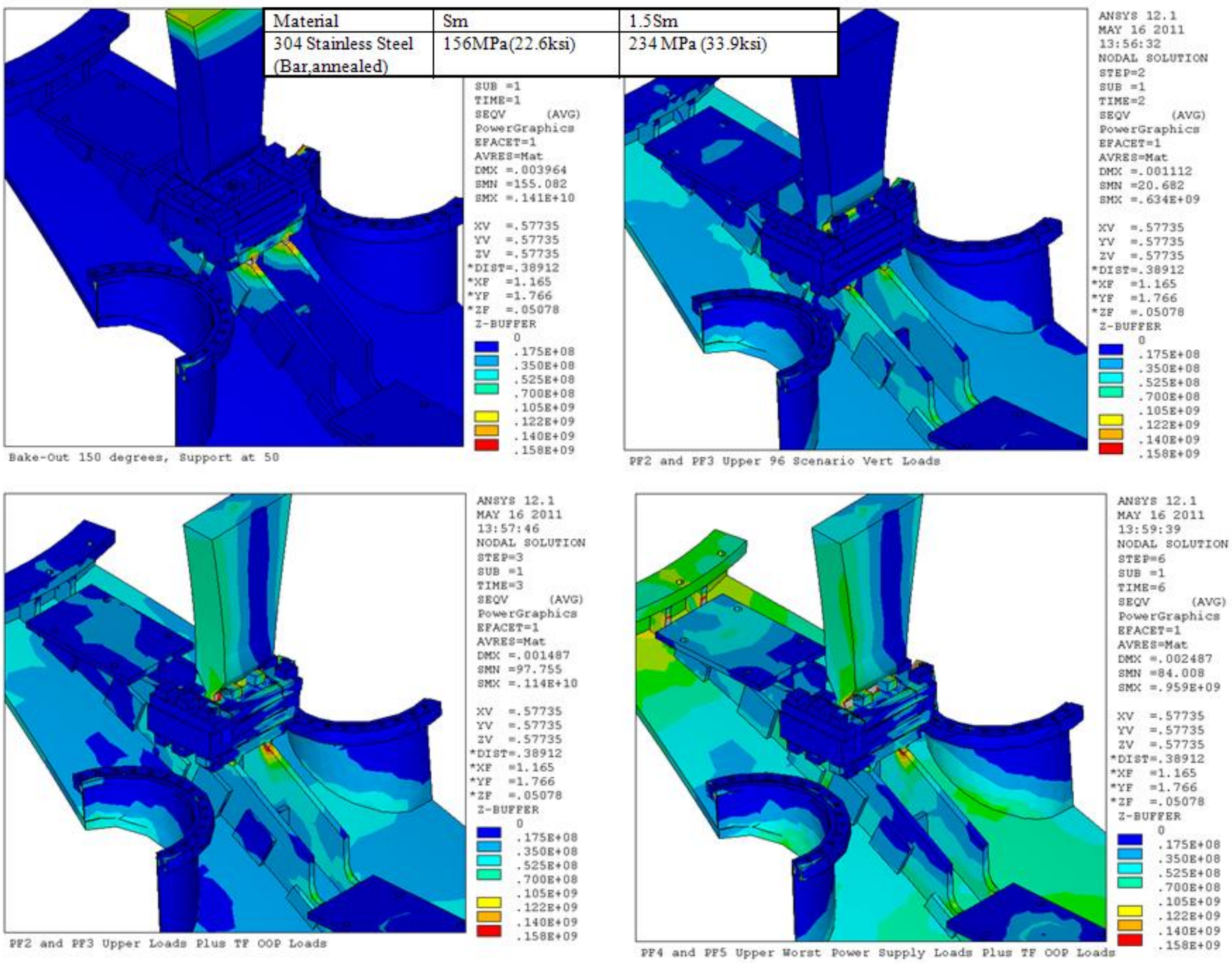


Figure 9.3.2 Dome Stresses in the 30 Degree Cyclic Symmetry Model

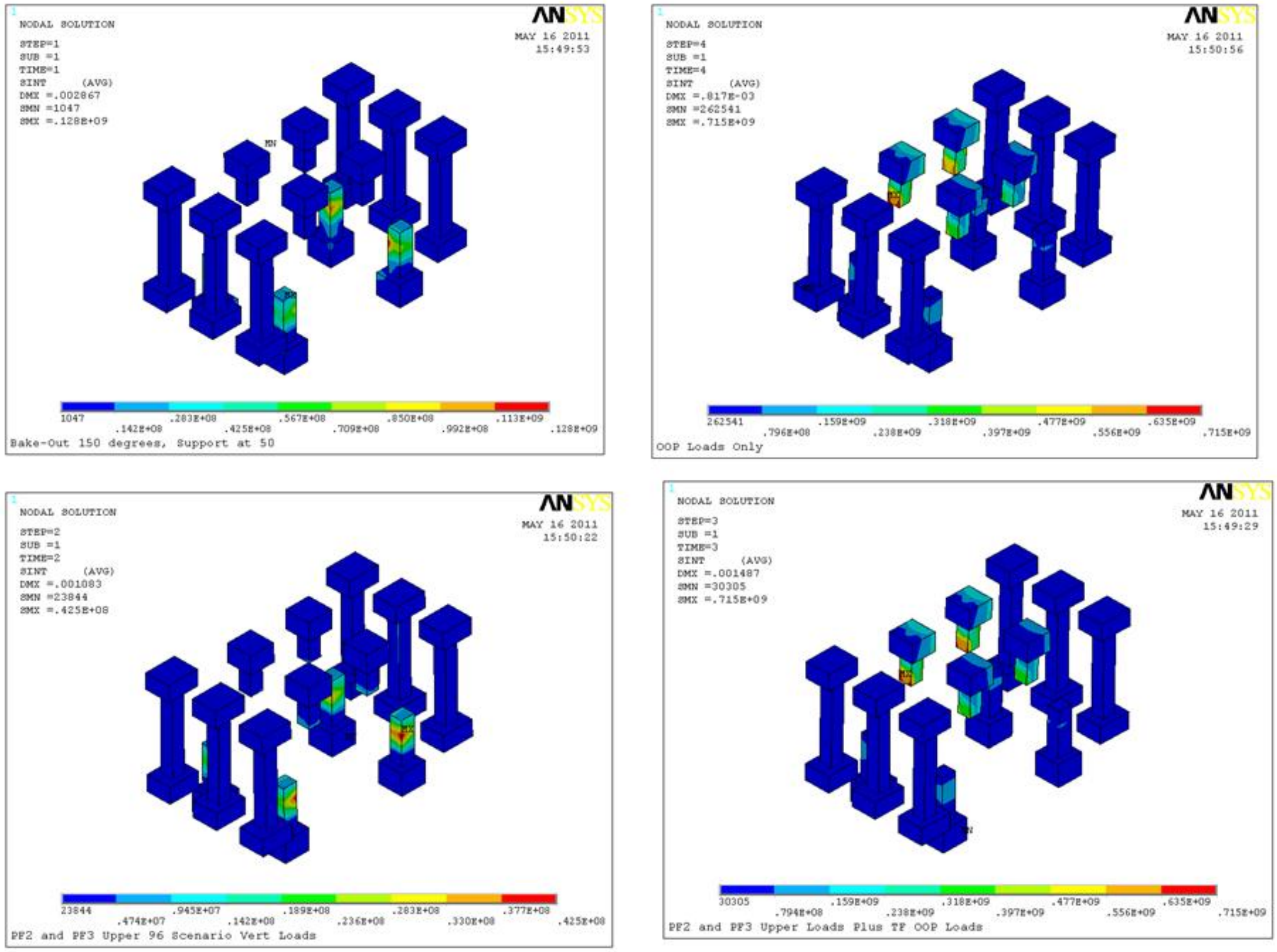


Figure 9.3.3 Bolt Stresses from the 30 degree Cyclic Symmetry Model

Significant stresses occur only in the four bolts that currently take the OOP shear load as shear across the bolt thread. The Upgraded design will employ "lips" on the sides of the sliding block assembly that will engage the plate welded to the ribs.

Fatigue

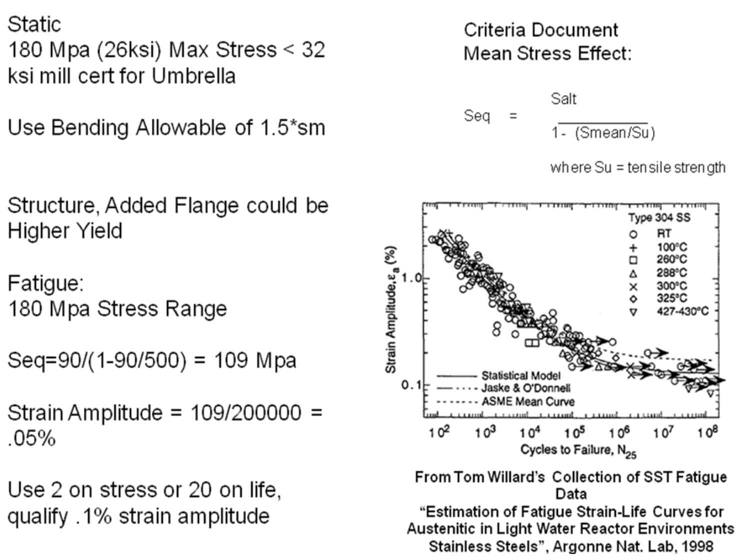
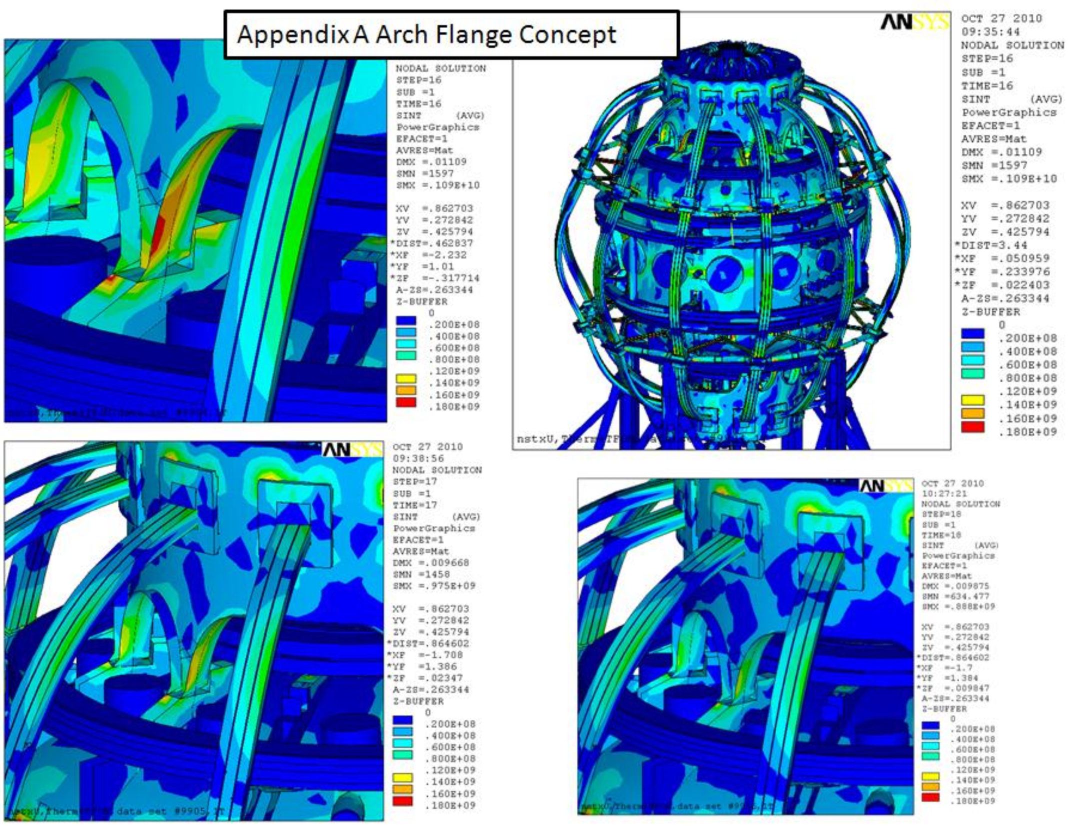


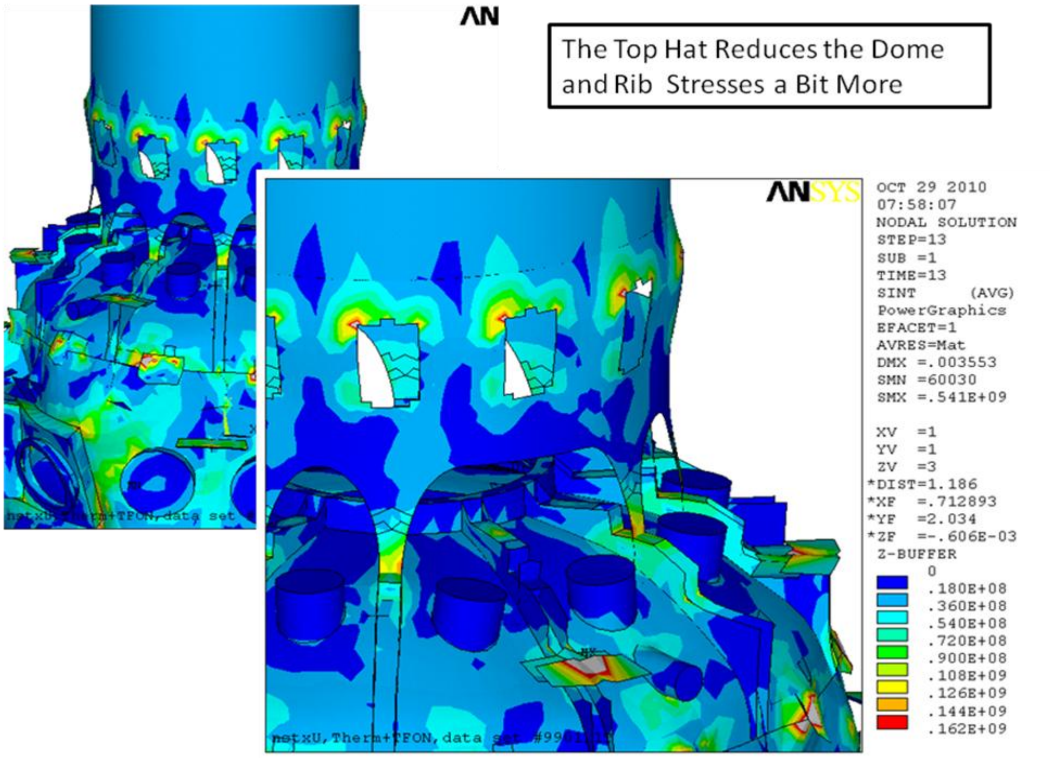
Figure 9.3.3

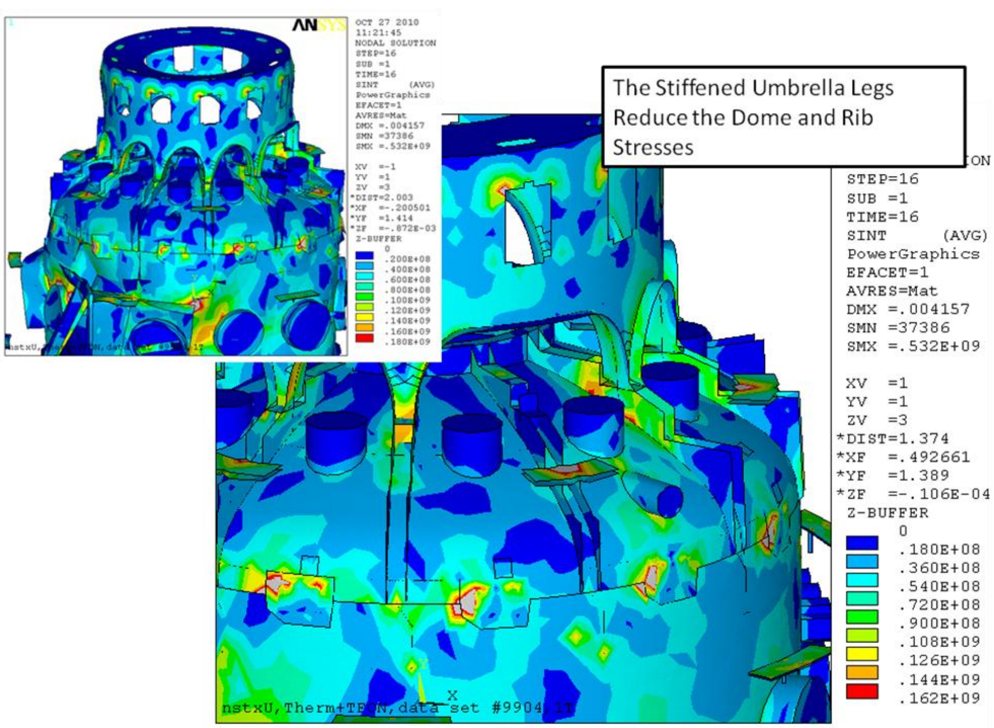
For 304 stainless, a 180 MPa stress range translates to a 90/(1-90/500) = 109 MPa equivalent R=-1 alternating stress. This is a strain amplitude of 109/200000 = .05%. Entering the SN curve(Figure 7.2.1 for 304 Stainless) and applying either 2 on stress or 20 on life yields an acceptable fatigue life meeting the GRD requirement of 60000 pulses.

Figure 9.3.4 Area Recommended for Inspection



Appendix B "Top Hat" Torque Frame





Appendix C
Dome Material Certifications

#1

Process Systems Int'l **Receiving Inspection Report**

Job No: V19077- **HEADS:** #1 BOTTOM HEAD

PSI P.O. # 558628 **ITEM #** 001

PSI MIC # D019 **HEAT #** 879461 /SL52960

DISCRIPTION: 133" ½ ASME F&D SA-240-

QUANTITY: 1

REVIEW MATERIAL CERTIFICATION: OK ARB 6-9-98

REVIEW RADIOGRAPHS: OK ALB 7-27-98

VERIFY DIMENSIONS; ROUNDNESS - ON MACHINE (RESTRAINED) WITHIN .050"

THICKNESS - .680"

CIRCUMFERENCE - 134.240"ϕ

VERIFY MAGNETIC PERMEABILITY - IN ACCORDANCE WITH SPECIFICATION V077-2-002, PARA. 2.4.

1.01mu – 1.05mu MEASURED BASEMATERIAL @ 0°, 90°, 180° 270° FROM WELDEDGE TO Top of Dome 6 places @ 6" SPACING.

1.05mu – 1.10mu SEAM WELD IN HEAD, except: area 2" ABOVE KNUCLE RAD MEASURES 1.1-1.2 @ 90° and 1.2-1.3 @ 180° AND A 4" LONG AREA IN THE MIDDLE OF A REPAIRED AREA NEAR TOP OF DOME MEASURES OVER 3.0mu. (THIS AREA WILL BE ORIENTED SO IT IS A NOZ-CUTOUT).

INSPECTED BY: Alan L Bradbrook **DATE:** 6-9-98

#2

Process Systems Int'l **Receiving Inspection Report**

Job No: V19077- **HEADS:** #2 TOP HEAD

PSI P.O. # 558628 **ITEM #** 001

PSI MIC # D019 **HEAT #** 879690/SL 01980

DISCRIPTION: 133" I/D ASME F+D SA-240

QUANTITY: 1

REVIEW MATERIAL CERTIFICATION: OK ARB 6-9-98

REVIEW RADIOGRAPHS: OK ARB 7/27/98

VERIFY DIMENSIONS; ROUNDNESS - UNRESTRAINED WITHIN 3/8"

THICKNESS - .672" – .678"

CIRCUMFERENCE - 134.263"φ

VERIFY MAGNETIC PERMEABILITY - IN ACCORDANCE WITH SPECIFICATION V077-2-002, PARA. 2.4.

1.01mu – 1.05mu MEASURED BASE MATERIAL @ 0°, 90°, 180°, 270° From Weld Edge to Top of Dome 6 places @ 6" spacing.

1.2mu – 1.3mu WELD SEAM IN HEAD Above Knuckle Radius for 30"

1.05mu – 1.1mu WELD SEAM IN HEAD below Knuckle Radius to WELD BEVEL.

INSPECTED BY: ARBradbury **DATE:** 6-9-98

Allegheny Ludlum CORPORATION
Jessop Plate Products Division

0-04657

Page 1

500 Green Street
Washington, Pennsylvania 15301

CERTIFIED MATERIAL TEST REPORT

PSI MIC NO. D019

Billto:
PLATE PROD DIV / A-L
1201 VALLEY ROAD
COATESVILLE PA
19320

Shipto:
PLATE PROD DIV / A-L
1201 VALLEY ROAD
COATESVILLE PA
19320

HELEN M. O'CONNOR
Quality Assurance Representat

PROCESS SYSTEMS INT'L., INC.
Reviewed this report and it complies with (SA)SB- 240 Gr. 304 1995 Edition, 97 Addenda
By AR Buckbrook Date 6-10-98

Memo No:142331-01

Our Order no: LP7800588
Your Order No:1089
Date: 01/03/98
DUAL CERT

JESSOP T 304 STAINLESS HRAP
ASTM A240-96; ASME SA-240-A95; AMS 5513F;

Heat	Slip	Lot No	Size	Pcs	Weight
879461	52960 D	39172	.6250 x 101.0000 x 350.0000	1	6587 GV-STOCK

Heat	C	MN	P	S	SI	NI	CR	MO	CO	CU	N
879461	.025	1.74	.03	.0004	.38	8.22	18.25	.40	.12	.36	.079

Lot No	Gauge	Yield Strength	Tensile Strength	Elong	Red. of Area	Hardness	Bend	Corrosion	Grain Size
39172	.6250	41.4 KSI	87.6 KSI	57.2	77.6	BHN163	OK	OK	

MATERIAL WAS NOT WELDED

Memo No:142399-01

Our Order no: LP7800588
Your Order No:1089
Date: 01/08/98
DUAL CERT

JESSOP T 304 STAINLESS HRAP
ASTM A240-96; ASME SA-240-A95; AMS 5513F;

Heat	Slip	Lot No	Size	Pcs	Weight
879461	52960 D	39178	.6250 x 101.0000 x 350.0000	1	6587 GV-STOCK

Heat	C	MN	P	S	SI	NI	CR	MO	CO	CU	N
879461	.025	1.74	.03	.0004	.38	8.22	18.25	.40	.12	.36	.079

Lot No	Gauge	Yield Strength	Tensile Strength	Elong	Red. of Area	Hardness	Bend	Corrosion	Grain Size
39178	.6250	42.9 KSI	88.0 KSI	54.0	77.1	BHN163	OK	OK	

MATERIAL WAS NOT WELDED

Memo No:143044-01

APPROVED
MAR 25 1998
Q.C. DEPT.

Our Order no: LP7426810
Your Order No:2022
Date: 01/19/98
DUAL CERT

JESSOP T 304 STAINLESS HRAP
ASTM A240-96a; ASME SA-240-A96; AMS 5513F
UNS 30400

EXCEPT AS OTHERWISE NOTED, THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH THE LISTED SPECIFICATIONS AND RESULTS CONFORM TO THE SPECIFICATION AND ORDER REQUIREMENTS. THE ABOVE INFORMATION HAS BEEN REPRODUCED FROM THE ORIGINAL CERTIFIED MATERIAL TEST REPORT.

ORIGINAL

Allegheny Ludlum Corporation
Jessop Plate Products Division

Page 2

500 Green Street CERTIFIED MATERIAL TEST REPORT
Washington, Pennsylvania 15301

MIC NO D019

Billto:	Shipto:	
PLATE PROD DIV / A-L	PLATE PROD DIV / A-L	
1201 VALLEY ROAD	1201 VALLEY ROAD	
COATESVILLE PA 19320	COATESVILLE PA 19320	HELEN M. O'CONNOR Quality Assurance Representa

Heat	Slip	Lot No	Size	Pcs	Weight
879690	01980 C	39287	.6250 x 90.0000 x 325.0000	1	5450 GV-76863

Heat	C	MN	P	S	SI	NI	CR	MO	CO	CU	N
879690	.025	1.75	.033	.0004	.40	8.18	18.23	.39	.14	.37	.09

Lot No	Gauge	Yield Strength	Tensile Strength	Elong	Red. of Area	Hardness	Bend	Corrosion	Grai Siz
39287	.6250	41.5 KSI	89.7 KSI	55.2	76.4	BHN163	OK	OK	

MATERIAL WAS NOT WELDED

PROCESS SYSTEMS INT'L., INC.
Reviewed this report and it complies with SA/SB- 240 Gr. 304
1995 Edition, 97 Addenda
By A L Bradbrook Date 6-10-98

MIC #
TOP HEAD HT-879690/SL 01980 D019

BOTTOM HEAD HT 879461/SL 52960 D019

APPROVED
MAR 25 1998
Q.C. DEPT.

EXCEPT AS OTHERWISE NOTED, THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED IN ACCORDANCE WITH THE LISTED SPECIFICATIONS AND RESULTS CONFORM TO THE SPECIFICATION AND ORDER REQUIREMENTS. THE ABOVE INFORMATION HAS BEEN REPRODUCED FROM THE ORIGINAL CERTIFIED MATERIAL TEST REPORT.

ORIGINAL

PSI MIC NO. D019

PG - 3 OF 4

TRINITY INDUSTRIES, INC.
HEAD DIVISION
11861 MOSTELLER RD * CINCINNATI OH 45241 * (513)-771-2300
MTR COVER LETTER

PROCESS SYSTEMS INTERNATIONAL INC
20 WALKUP DR
WESTBOROUGH MA 01581-1019

ATTN : PAUL CLARK

REFERENCE : CUSTOMER P/O 558628 , TAG #
TRINITY S/O 2-29237

GENTLEMEN :

ATTACHED ARE COPIES OF MILL TEST REPORTS FOR THE FOLLOWING MATERIAL PROVIDED ON YOUR REFERENCED PURCHASE ORDER.

LABOR & MATERIAL
2-SA240-304 ASME-F&D HEAD 133.0000 ID 0.6250 NOM
100.8000 RD. 14.0000 ICR. WITH 2.5000 SF.

HEAT NUMBER

879461-52960 HC*
879690-01980 HC*

ALL HEADS WERE COLD FORMED AND ARE IN COMPLIANCE WITH REGULATION UG - 81 AND UG - 79 AS STATED IN SECTION VIII DIVISION I OF THE ASME BOILER AND PRESSURE VESSEL CODE. HEADS WERE FORMED WITHOUT COMING IN CONTACT WITH MERCURY OR ANY OF IT'S COMPOUNDS

ALL HEADS WERE ANNEALED AT 1950 +/- 50 F FOR ONE HOUR PER INCH AND WATER QUENCHED.

IF YOU HAVE ANY FURTHER QUESTIONS CONCERNING MILL TEST REPORTS ONLY, PLEASE CONTACT ME IN CINCINNATI, OHIO AT 1-800-543-1644

VERY TRULY YOURS,

TRINITY INDUSTRIES, INC
HEAD DIVISION

FORM U-2A MANUFACTURER'S PARTIAL DATA REPORT (ALTERNATIVE FORM)
A Part of a Pressure Vessel Fabricated by One Manufacturer for Another Manufacturer
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured and certified by Trinity Industries Inc. Head Division 11861 Mosteller Rd., Cinti, OH 45241 (Name and address of Manufacturer)

2. Manufactured for Process Systems International Inc, 20 Walkup Dr., Westborough MA 01581-1019, PO#5586 (Name and address of Purchaser)

3. Location of installation Unknown (Name and address) PSI MIC NO. D019 PC-4 of 4

4. Type: ASME(2PC)Heads 133"ID x .625 NOM THK (Description of vessel part (shell, two-piece head, tube bundle)) 2-29237-1&2 (Mfg's. serial No.) (CRN) (Mat'l. Bd. No.) (Drawing No.) (Drawing prepared by) 1998 (Year built)

5. ASME Code, Section VIII, Div. 1 1995 Edition 1996 ADD (Edition and Addenda (date)) (Code Case No.) (Special Service per UG-120(d))

6. Shell (a) No. of course(s): (b) Overall length (ft & in.):

Course(s)			Material	Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter, in.	Length, ft & in.	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff.	Temp.	Time

7. Heads: (a) SA240-304 S/S * (Mat'l Spec. No., Grade or Type) H.T. – Time & Temp.) (b) (Mat'l Spec. No., Grade or Type) H.T. – Time & Temp.)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)		.573		100.8	14							1	Full	
(b)														

If removable, bolts used (describe other fastening) (Mat'l Spec. No., Grade, Size, No.)

8. MAWP ______ (Internal) ______ (external) psi at max. temp. ______ (Internal) ______ (external) °F. Min. design metal temp. ______ °F at ______ psi.

9. Impact test ______ (Indicate yes or no and the component(s) impact tested)

10. Hydro., pneu., or comb. test press. ______ Proof test ______

11. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Flange Type	Material		Nozzle Thickness		Reinforcement Material	How Attached		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	

12. Supports: Skirt ______ (Yes or no) Lugs ______ (No.) Legs ______ (No.) Others ______ (Describe) Attached ______ (Where and how)

13. Remarks: No design functions performed by Trinity Industries Inc. Head Division
Customer is responsible for specifying minimum design metal temp.
* Heads were annealed at 1900°F minimum 1 hour per inch and water quenched.

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of material, construction, and workmanship of this pressure vessel part conform to the ASME Code for Pressure Vessels, Section VIII, Division 1.

U Certificate of Authorization No. 25,479 Expires March 25, 2000

Date 5-27-98 Name Trinity Industries Inc. Head Division (Manufacturer) Signed [signature] (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of Ohio and employed by Commercial Union Insurance Companies of Boston, MA have inspected the pressure vessel part described in this Manufacturer's Data Report on 5-27, 19 98, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel part in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel part described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 5-27-98 Signed [signature] (Authorized Inspector) Commissions [signature] (Nat'l Board (incl. endorsements), State, Province and No.)

(12/91) This form (E00121) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300 REPRINT 3/92

Run Date: 28-JUL-1998 Time: 10:14 AM Process Systems International, Inc. User: ALB Page 00001

P O History by Order#

PO: 558628-00 Vendor: 43718 Buy-From: 43718 TRINITY INDUSTRIES INC
Date: 3/18/98
11861 MOSTELLER ROAD
SHARONVILLE, OH 45241
ATTN: DAVE SCHAEFER
(800)543-1644

Ship to:01 PROCESS SYSTEMS INTERNATIONAL
20 WALKUP DRIVE
WESTBORO, MA 01581

Buyer: 03
Fob: 1
Ship Via: 1
Terms: 1

Lin Item Number		UM	Ordered Cost($)	Ordered Qty	Received By	Received Qty	Inspection Qty	Rej+Disp Code	Rej+Disp Qty	Change to Inv	Voucher Amt Dollars
1 V077M202 1	HEAD,SST304 SA240 CMTR,ASME F&D,133.000I.D.,.625 NOM THK										
3/17/98 16:15:46	Add Rq: 5/18/98 Pm: 5/18/98	EA	7736.0000	2							
3/18/98 08:28:45	Cncl		7736.0000	2-							
3/18/98 09:20:35	Add Rq: 5/18/98 Pm: 5/18/98	EA	7736.0000	2							
6/10/98 10:41:55	Rcpt Dt: 6/10/98 DELIVERED TO NIMCO PER LARRY		7736.0000		JRW	2				2	
6/10/98 10:41:55	Qty Sent Inspct: 2						2			2-	
6/25/98 10:35:37	Qty Passed Insp: 2 REC,D AT NIMCO PER LARRY.						2-			2	
7/01/98 09:56:27	Vouch Number:104463 Inv:5-8945 for 2 EA Job:V19077										[redacted]
	Line totals			2		2	0		0	2	[redacted]

7 RECORDS SELECTED

RECEIPT INSPECTED AT VENDOR WITH
MIKE VIOLA OF PPPL ON 6-9-98

[signature]